NASA TECHNICAL MEMORANDUM

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INFORMATION TRANSFER SATELLITE SUMMARY REPORT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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* INFORMATION TRANSFER SATELLITE

SUMMARY REPORT

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This report contains an Introduction which describes the study structure and provides some needed definitions. It describes the systems analysis techniques and methodologies which made such a large undertaking tractable; gives a brief description of the market analysis which studied the many potential uses of INFOSATS in American life in the future; discusses the 20 or 30 resulting INFOSAT missions; and provides a set of conclusions concerning where the Nation is headed in information transfer, how INFOSATS can help, and what remains for NASA to do in the resulting information transfer revolution.

*INFOSAT

CONTENTS

OBJECTIVES *

The Nation is in the midst of a far reaching revolution in the ways that it transfers information and in the amount of such information. It is heading toward a state commonly called "The Wired Nation", featuring such services as checkless banking, programmed home education, and on-demand entertainment, education, and news, to mention only a few. INFOSATS will play a complex and important role in this revolution, particularly if their planning is farsighted and comprehensive and the development of socially useful features is timely. NASA had the initial role in fostering INFOSAT development. If this original role can be resurrected, and if NASA is ready for the new challenges, then NASA can still be a powerful voice in insuring that this new phase of INFOSAT development takes socially beneficial directions that will reflect credit on the space program.

This report attempts to highlight key facts contained in a series of reports devoted to this objective, and to serve as a convenient general summary of several thousand pages of technical material.

SUMMARY REPORT: OBJECTIVES

- QUESTIONS ADDRESSED
  - WHERE IS NATION HEADED IN INFORMATION TRANSFER ?
  - WHAT ARE INFOSAT ROLES ?
  - WHAT IS NASA'S ROLE ?
- GOALS
  - HIGHLIGHT KEY FACTS
  - SUMMARIZE THOUSANDS OF PAGES OF DETAILED ANALYSIS/ USER CONTACT DATA

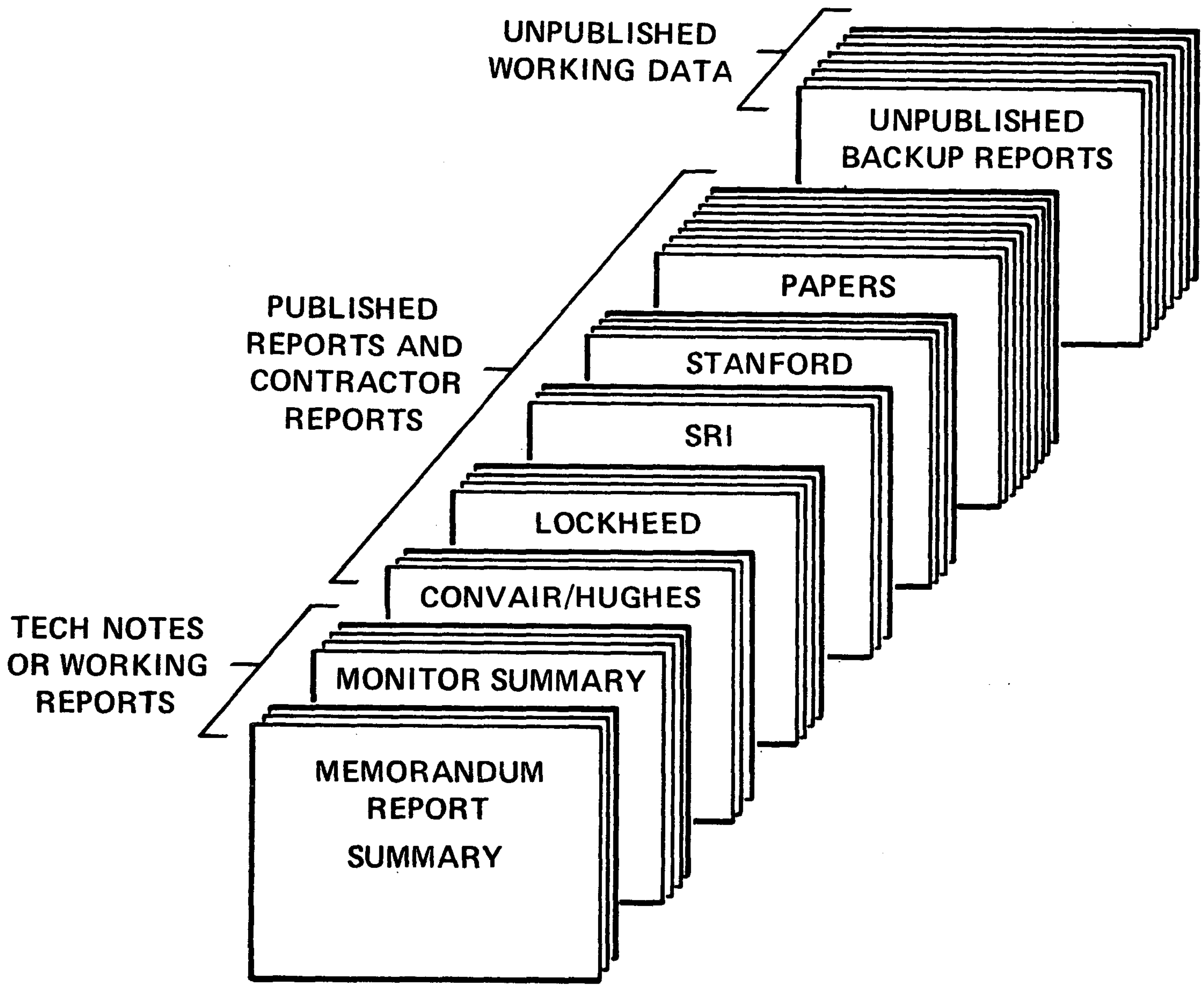
INTRODUCTION *

INTRODUCTION

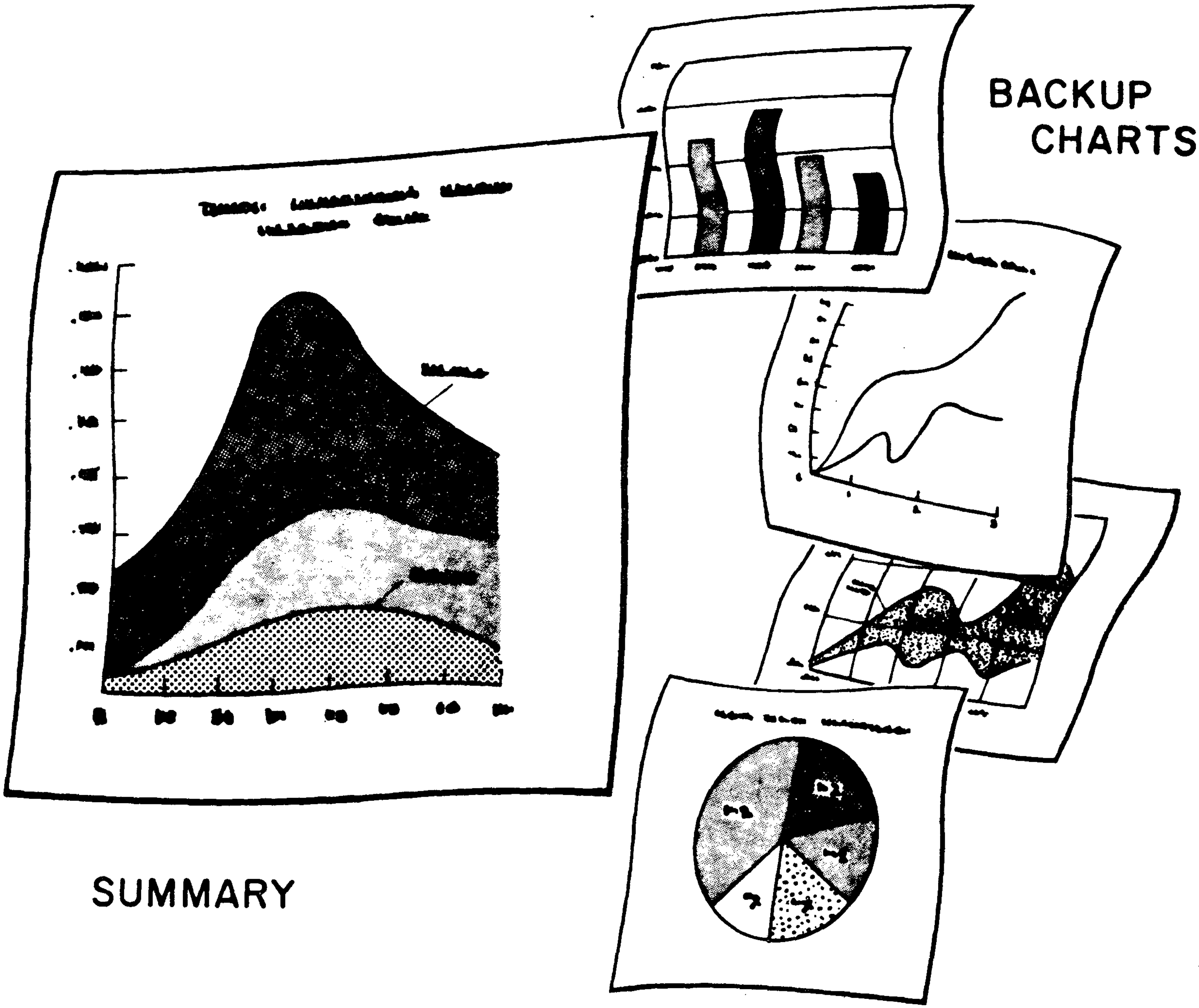
- STUDY STRUCTURE

- DEFINITIONS

This summary is founded upon nearly a dozen published contractor reports, several published papers, a large volume of unpublished backup reports concerning technical aspects and the results of contacts with nearly 500 users of information transfer.


UNPUBLISHED
WORKING DATA
UNPUBLISHED
BACKUP REPORTS
PUBLISHED
REPORTS AND
CONTRACTOR
REPORTS
PAPERS
STANFORD
SRI
LOCKHEED
CONVAIR/HUGHES
TECH NOTES
OR WORKING
REPORTS
MONITOR SUMMARY
MEMORANDUM
REPORT
SUMMARY

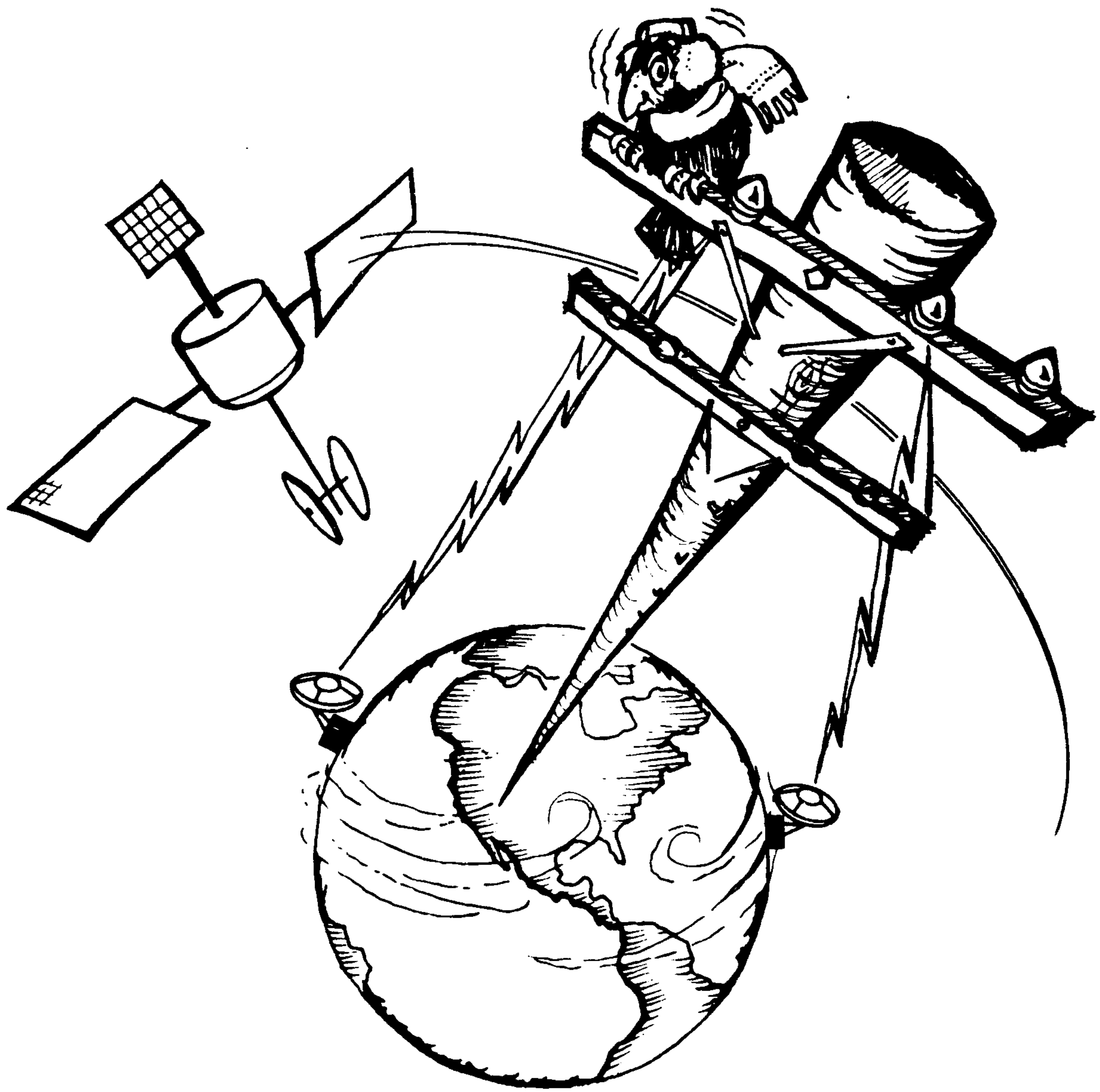
Since this report is intended as a general summary of a larger volume of backup data and reports, each chart in this summary can be thought of as expanding into several charts in backup volumes.


BACKUP CHARTS
SUMMARY

There is a commonly held misconception that INFOSATS are "merely a 22,000 mile high telephone pole," or are "merely a piece of bent pipe" for messages, etc. This view obscures the more important unique characteristics of the satellite. Viewed in this way, the satellite, which is inherently more wasteful of precious spectrum than the coaxial cable and the waveguide, would hardly be worth developing.

It is the many unique new uses that become possible because of the satellite's synoptic view of nearly a hemisphere that deserve the emphasis.

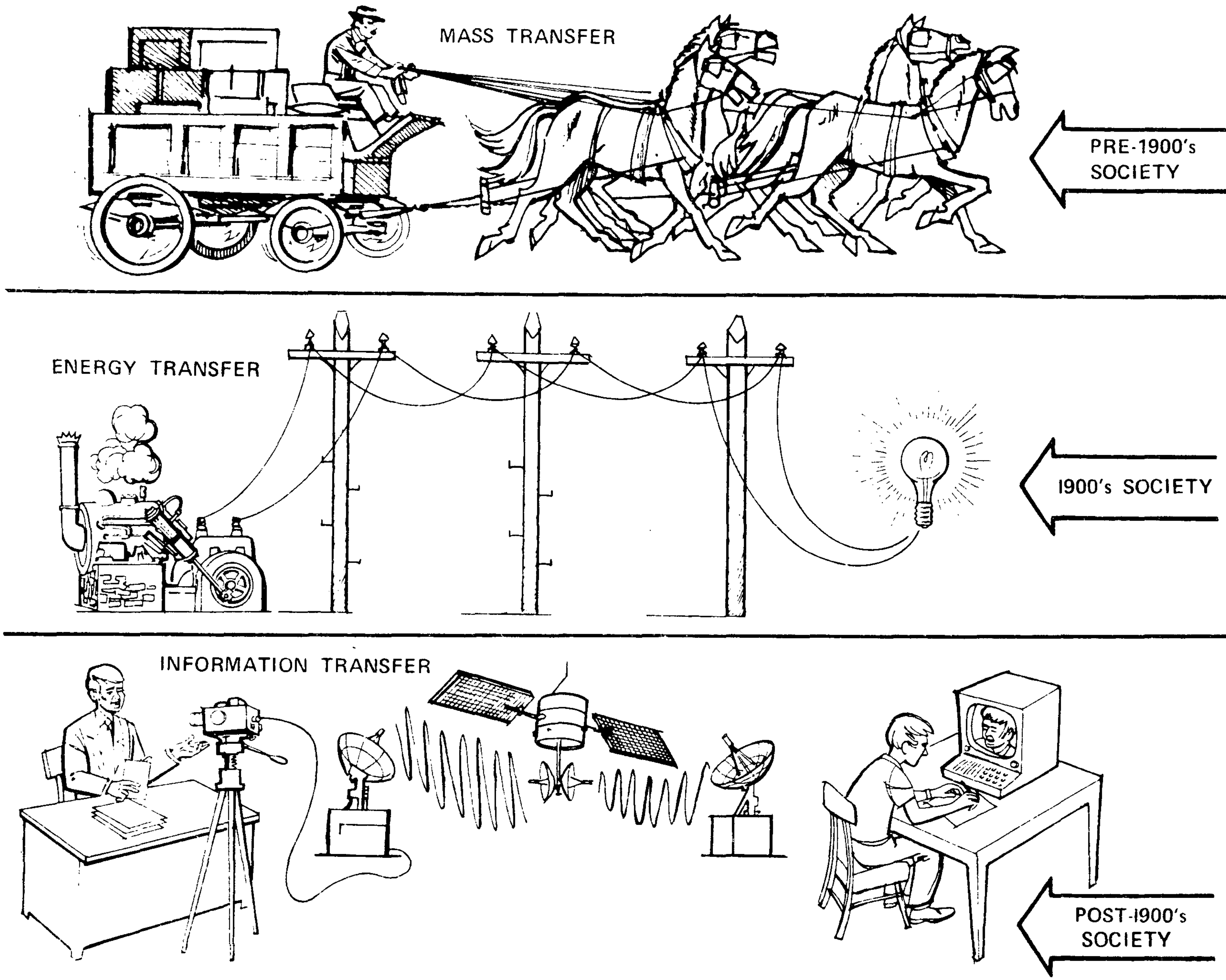
- INFOSATS ARE MORE THAN JUST A 22,000 MILE HIGH "PHONE POLE"
- UNIQUE USES NEED MORE ATTENTION



Because the term communications satellite was found by experience to evoke primarily images of point-to-point relay satellites merely replacing cables or microwave links, there was a need for an entirely new term to convey the impression of a satellite being uniquely used for an entire spectrum of information transfer uses that it uniquely could perform. INFOSATS, or Information Transfer Satellites, are not merely cable substitutes or competitors. The entire study has concentrated on their unique uses.

Society in the pre-1900 time frame was characterized by an economy based on the transfer of masses from one physical location to another, or "mass transfer", and with growth rates characterized by doubling periods of 20 to 40 years. Society in the early 1900's based its growth more and more on the transfer of energy, a form typified by growth that exhibits doubling periods on the order of 10 to 12 years. In the late 1900's society will be based more and more on services than upon goods production, thus involving it more and more in the transfer of information--since services use little energy or goods--so that more and more society's growth will be related to the 5 to 6 year doubling periods characteristic of information transfer.

HUMAN AFFAIRS – USING MORE AND MORE INFORMATION TRANSFER



SYSTEMS ANALYSIS METHODOLOGY *

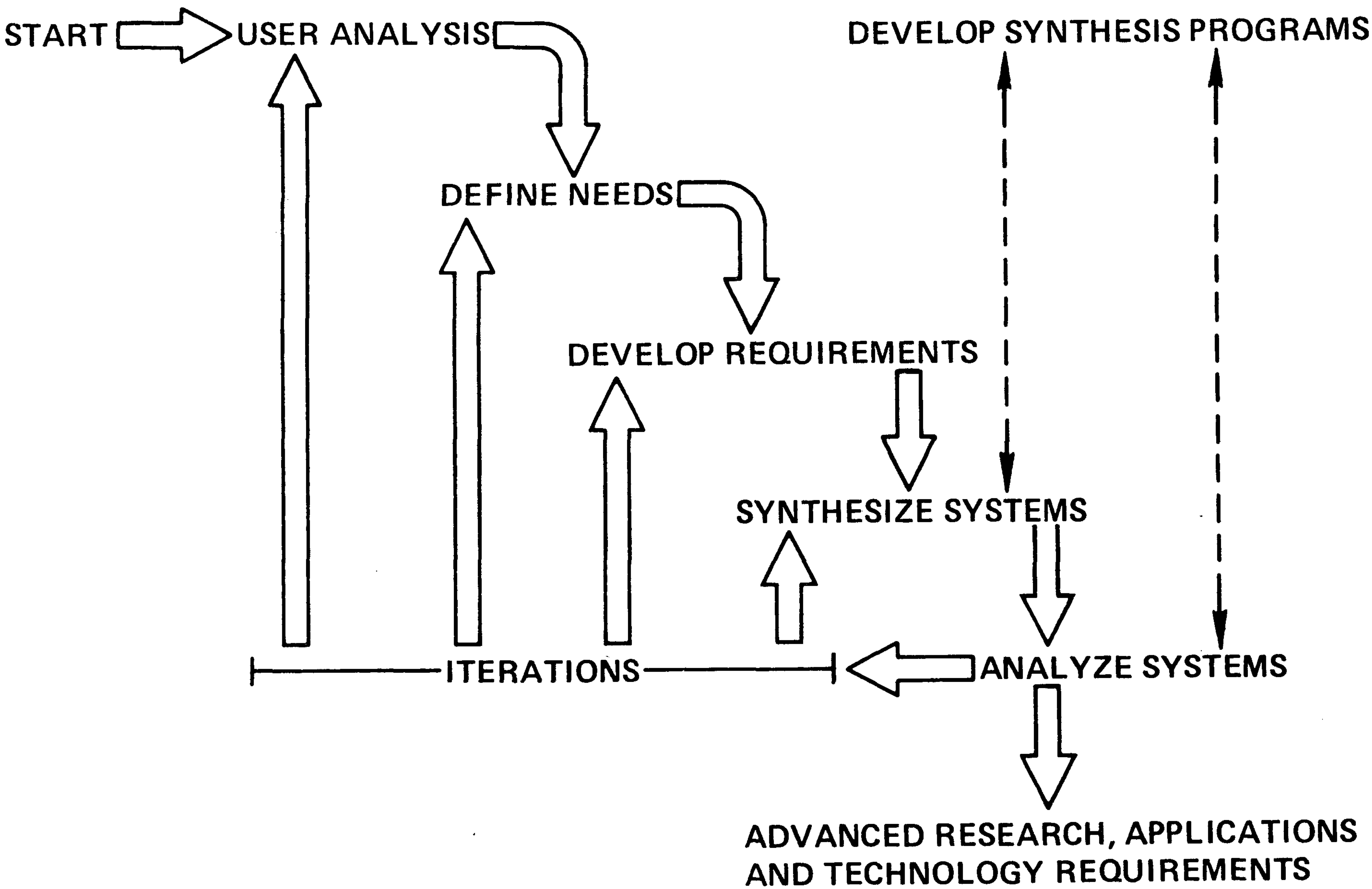
This section describes the systems analysis methodology. Flow diagrams describe the flow of information and the phasing of analytical tasks within the study. Information transfer scenarios are given as a compact way of describing the forecasts that were made of the future environment of information transfer. Information needs lists describe the requirements for information services that were postulated for the 1985 timeframe. Finally, several examples are given of the systems analysis results.

SYSTEMS ANALYSIS METHODOLOGY

- FLOW DIAGRAMS OF ANALYSIS
- INFORMATION TRANSFER "SCENARIOS"
- INFORMATION TRANSFER NEEDS LISTS
- EXAMPLES

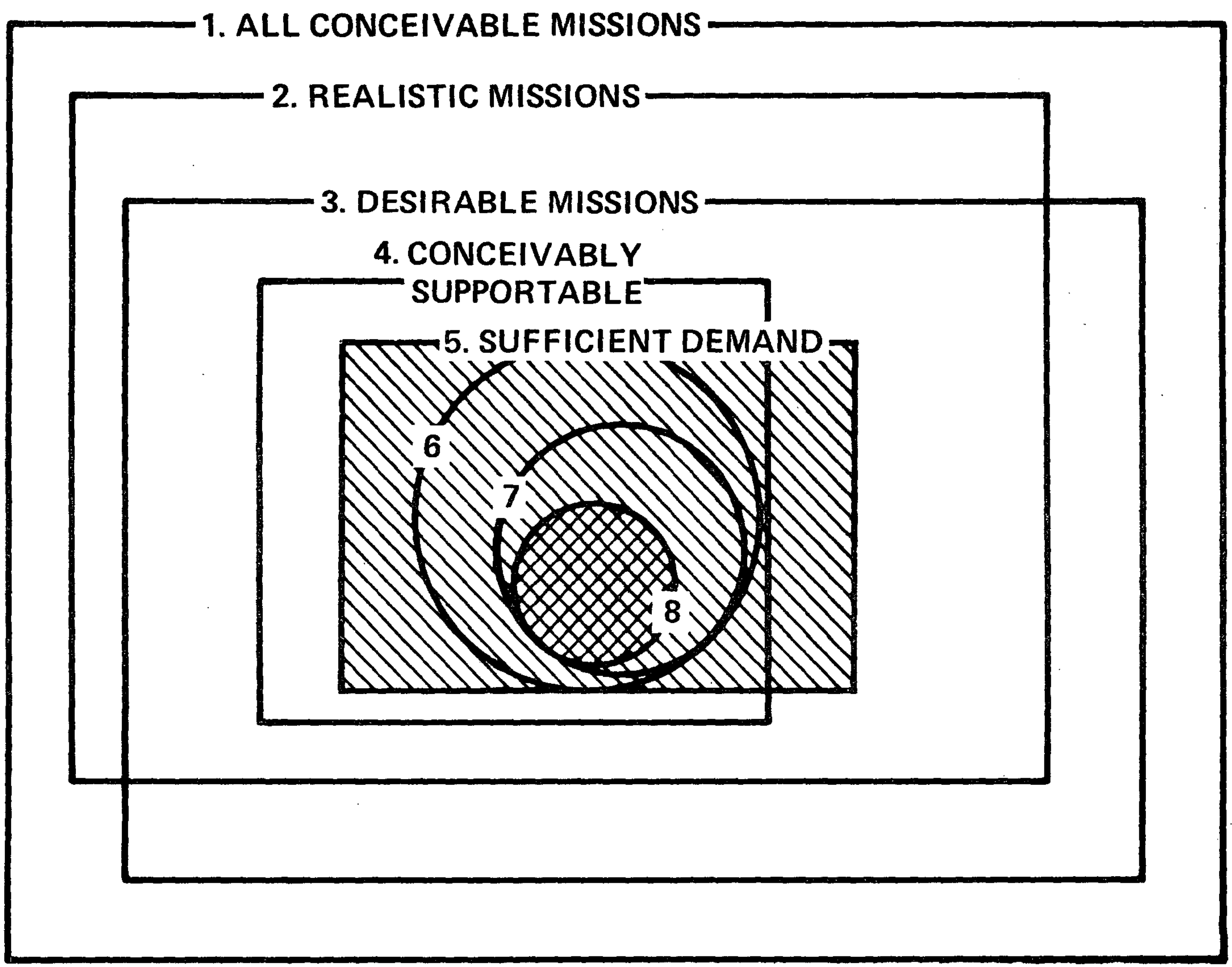
The study of the infrastructure of information transfer is a vast undertaking. There is neither a general theory of human communications nor of the economics of the telecommunications industry, and social impacts are at best poorly comprehended. A carefully structured methodology was required if useful results were to be collected in spite of the poor baseline. The methodology was characterized by the attempt to derive all technology requirements directly or indirectly from user needs. Direct relation of technology needs to user needs was used wherever possible. This task is still in progress. Wherever possible quantitative methods were used, and in some cases the methods were computerized. The study involved much iteration between the user's requirements and technological feasibility steps. A large number of possible initial concepts was successively reduced to a more workable number by applying social and technical feasibility criteria and benefit measures. The amount of effort devoted to each potential mission, service, or satellite use at each stage was kept roughly proportionate to its apparent importance at each stage.

STUDY METHODOLOGY



The phasing of the investigation was such that an attempt was made to consider all conceivable missions in the course of the study. Realism criteria were applied to screen out such missions as "commercial use of extrasensory perception", and similar criteria were used to eliminate potential missions which were feasible but hardly desirable, such as the "Big Brother" type of application. The remaining missions were subjected to economic screening to determine whether they could be afforded, the demand was estimated to determine whether it was sufficient, the terrestrial competition was considered both from a market standpoint and considering the possibility of augmenting, sharing and other complementary use. And finally, for those dedicated missions that did not survive the screening individually an attempt was made to determine whether there might be selected combinations of dedicated missions that would satisfy the criteria as a multipurpose mission.

PHASING OF INVESTIGATION



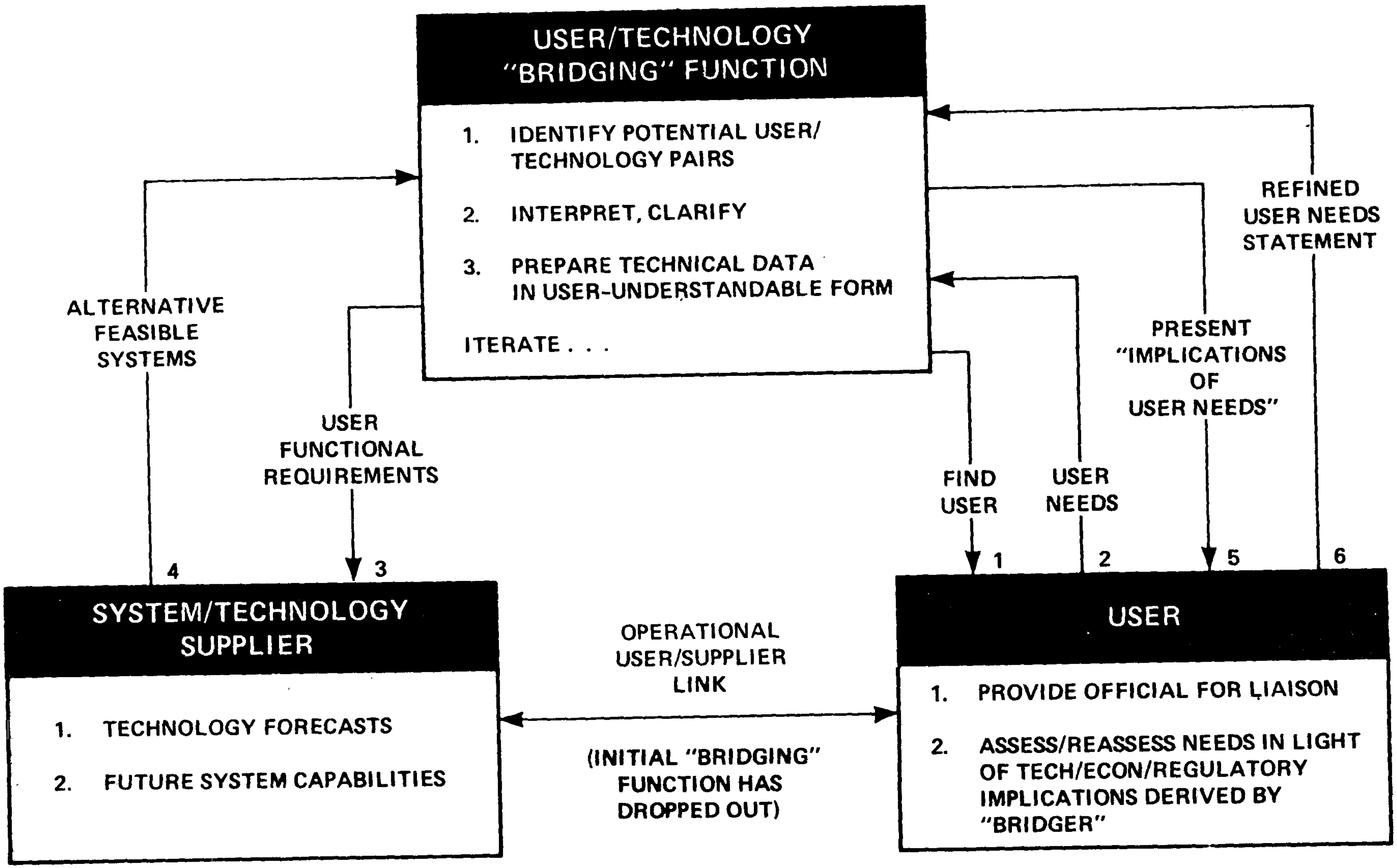
6. ECONOMICALLY FEASIBLE. 7. AUGMENT EXISTING CAPABILITY. 8. MULTIPURPOSE

One of the most significant features of this study has been that the user has been at the focus of the study from the outset. The chart on the facing page describes the approach taken for dealing with users. It was found to be highly useful in this study and is presented in the expectation that our experience with it may be useful in future related studies, such as in Earth resources and aeronautical applications satellites.

The basic idea is that there is a need for a technology/user "bridge" through which the basically different objectives of the user and the technologist may be reconciled. Very often the technologist is so unaware of user requirements for his technology and systems that he is hardly able even to identify a potential user. When he identifies the user he cannot understand his needs or, in many cases, even his jargon. The user is similarly unaware of the technological implications of his requirements and must be coaxed, through a slow iterative process, to reveal his requirements. This is particularly true with respect to the relative importance of the requirements and the user's relative willingness to change different requirements in light of the technological implications.

A bridging function ideally would represent a small group of systems analysts who serve to catalyze the process of user/technologist interaction until cognizant technologists and user representatives have been identified and thoroughly introduced to each other's problems and needs. After this the bridging function can change into a consulting role and, finally, can be omitted entirely. The key to success is to note that it is not possible to determine a user's requirements in one visit and design them into a system. Rather a complex interaction must begin with the user and the requirements must be arrived at iteratively. First the requirements must be analyzed and parametric tradeoffs made based on guesses of changes the user conceivably might want to make. These serve as the basis for a second discussion during which, or after which, the user requirements usually change. At this point it may even be determined that the wrong user representative has been contacted, in which case efforts must be made to select the correct representative. After a series of such iterations, somewhat accurate requirements are derived by the mutual action of both the technologist and the user.

APPROACHES TO TECHNOLOGY/USER BRIDGE



Future scenarios provided the context for extended forecasts that were made throughout the study, for the various needs research tasks, and for the assessment of priorities. The scenarios were updated by iteration as the study proceeded.

Some basic trends discerned were an explosive growth that shows no signs of saturation; an increasing diffusion of information transfer innovation outward toward the smaller user; an increasing fraction of digital data; and a rapidly increasing percentage of all information transfer that takes place at great distances.

INFOSAT CONCEPTS - FUTURE

NOW – 1975

- DATA SYSTEMS CENTRALIZED
- REMOTE DATA BANK ACCESS
- LIBRARY/BANK AUTOMATION

1975 – 1985

- DIRECT BROADCAST T.V.
- DIGITAL DATA EQUALS ANALOG
- COMMUNICATIONS REPLACING TRAVEL

1985 – 1995

- EXTEND ABOVE SYSTEMS TO WORLD
- DIGITAL HOME TERMINALS
- COMPUTERS TO HOMES VIA CATV

The near future scenario is dominated by the merging of four far reaching revolutions--the computer, telecommunications, low cost terminals, and satellites. The primary impact will be felt in large institutions that can take advantage of nationwide networks. The impact on individual homes will in this time period still be the indirect effects due to the primary impact on the institutions the householder deals with. Electronics will make some slight inroads into the formal educational process and even larger inroads into the beyond-school educational processes. These will give us only a foretaste of the things to come.

NEAR FUTURE SCENARIO

1965 – 1975

- DATABANK NETWORKS
- AUTOMATED LIBRARY NETS
- DIRECT RADIO SATELLITES FEASIBLE
- CASHLESS SOCIETY BEGINS
- WIDESPREAD DIGITAL BUSINESS NETS
- COMPUTERS EVOLVE TOWARD UTILITY
- LIMITED DIRECT TV TO AUGMENTED RECEIVERS
- SATELLITE "HOTLINE" USES
- — — — — — — — — —
- — — — — — — — —

In the middle future, 1975 to 1985, the major services will extend to homes primarily via cable TV, which will have achieved virtual saturation of the market by about 1980. The substitution of communications for travel has never yet been highly visible, although extensive--in this timeframe it will become so extensive that it will be very noticeable, primarily because of the increasing relative economy and convenience of communications over travel. Teachers will begin to be replaced more and more by improved electronic education devices. Professionals such as doctors and lawyers will be "amplified" and their services will be extended by availing themselves of such things as teleconferencing, remote diagnosis, computer aided diagnosis, etc. The mailman will be on his way to vanishing, just as the Western Union boy of an earlier time vanished, and will be replaced largely by electronic telemail terminals.

MIDDLE FUTURE SCENARIO

1975 – 1985

- EXTENSION OF CLASSROOMS TO HOME
- PUBLIC ACCESS TO SCHOOL RESOURCES - ELECTRONIC
- MOST COMMUNICATIONS DIGITAL
- COMPUTER UTILITIES TO PRIVATE HOMES
- VIDEOPHONE BEGINS REPLACING TRAVEL
- WIDESPREAD REMOTE MEDICAL DIAGNOSIS
- ELECTRONIC MAIL DELIVERY
- — — — — — — — — —
- — — — — — — — —

The 1985 to 1995 timeframe will see the emergence of a "transparent" knowledge utility, in which every citizen of the advanced countries will have immediate, undistorted access to the accumulated knowledge of mankind on demand. Our conventional ways of initially educating ourselves and maintaining our career skills throughout a lifetime of one or more careers will have taken such a different form through continued penetration of electronics into the educational process that they would be largely unrecognizable to us. Total access to knowledge will have made private research by individual professionals, who will by then be a very large class, into a thriving industry. The world will still be divided into "have" and "have not" nations, but the intelligentsia of the less advanced nations, together with increasing proportions of their less well educated and less affluent masses will be able to avail themselves of many of these sophisticated information transfer services by satellite contact with the more advanced nations. The limitations will be largely political rather than economic, on the model of South African television today.

FARTHER FUTURE SCENARIO

1985 – 1995

- CHEAP, MULTIPURPOSE HOME COMMUNICATIONS TERMINAL
- GLOBAL VILLAGE
- MOST EDUCATION AT HOME TERMINAL
- MOST HOME COMMUNICATION DIGITAL
- BEGIN LANGUAGE-INDEPENDENT COMMUNICATIONS
- COMPUTER UTILITY TO MANY HOMES
- FULL OPERATION COMPUTER UTILITY TO BUSINESSES
- DIRECT SATELLITE TO MOST NEIGHBORHOODS OR CATV HEADERS
- __ __ __ __ __ __ __ __ __
- __ __ __ __ __ __ __ __

In the study, demand forecasts were used to identify promising user needs which were then studied individually through research and user contacts. Services were then synthesized from these "demands". Services that had features in common were then grouped into "missions". Multipurpose INFOSAT configurations were then synthesized from these dedicated "missions".

NEEDS HIERARCHY - TERMINOLOGY

- IDENTIFY USER NEEDS FROM DEMAND FORECASTS
- SYNTHESIZE SERVICES FROM DEMANDS
- LOGICALLY GROUP COMMON SERVICES INTO "MISSIONS"
- SYNTHESIZE MULTIPURPOSE INFOSATS FROM DEDICATED "MISSIONS"

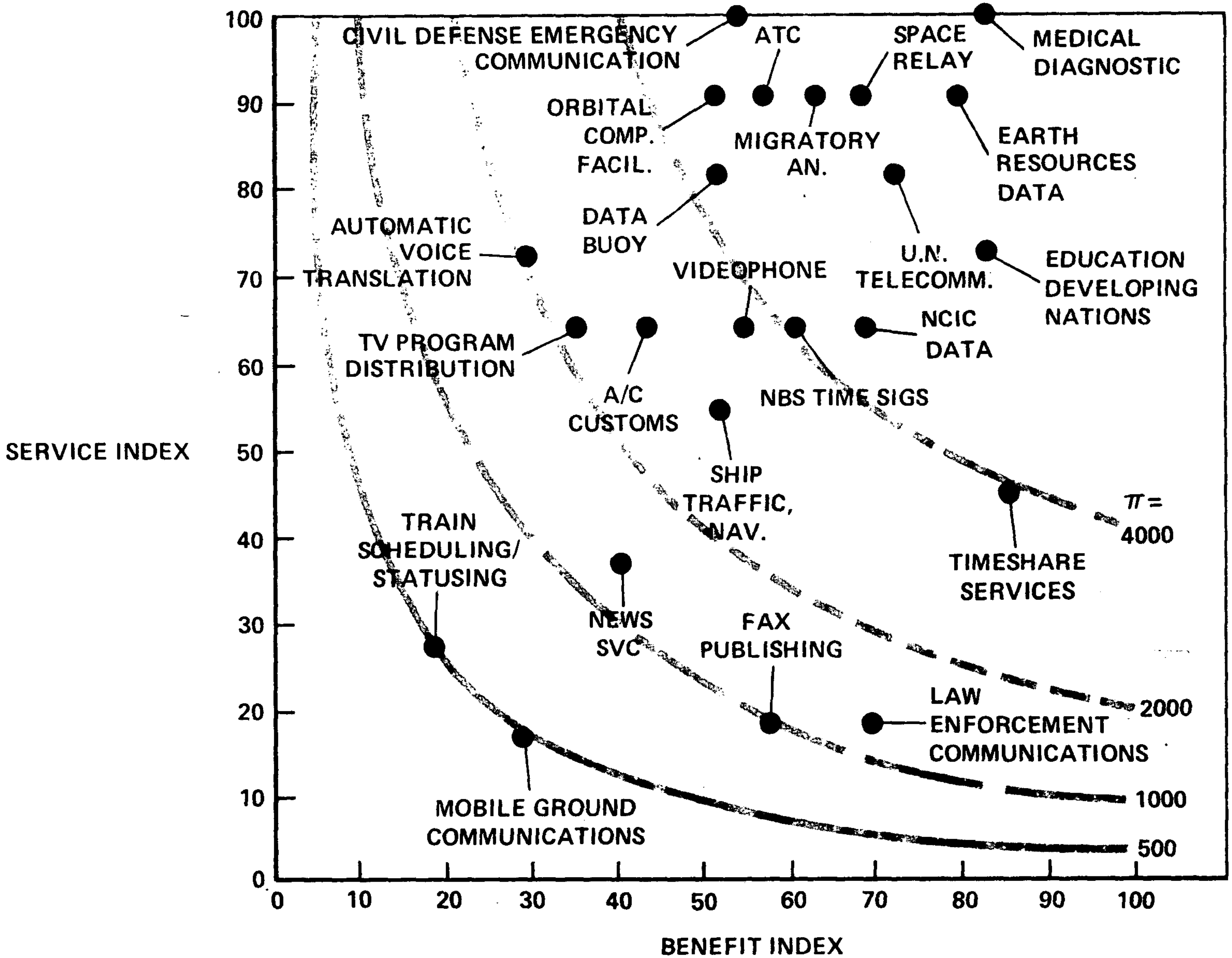
Over 500 conceivable services were evaluated and a rank was assigned. Sixty-two of the best were selected for detailed analysis and about half of these were selected for systems study. The criteria used in screening included such factors as cost of the service, existence of media competing with the satellite, and unique satellite capability. Fourteen "types" of satellite application are presented in the list on the facing page. They are roughly in order of priority at the mid-stage of the study.

PROMISING INFOSAT CONCEPTS

COMPUSAT.	INFO UTILITY, COMPUTER NET
MEDSAT	MEDICAL, BIOMEDICAL NET
CATSAT	CATV SERVICES INTERCONNECT
EARTHSAT.	EARTH RESOURCES DATA RELAY
EDSAT	EDUCATION NET
METSAT	GLOBAL WEATHER DATA RELAY
DOM-EDSAT	DOMESTIC EDUCATION NET
TRACKSAT.	SPACE DATA RELAY
MOBILSAT	MOBILE TELECOMM. SERVICES
TELESAT.	TELECONFERENCE "COMMUNITIES"
AIRSAT.	AIRCRAFT COM. SERVICES
WORLDSAT	INTERNATIONAL "HOTLINE"
BUSHSAT.	COM. SERVICES TO REMOTE AREAS
HOMESAT	SPECIAL EDUCATION SVC TO HOMES
— —.	— — — — — — —
— —.	— — — — — — —

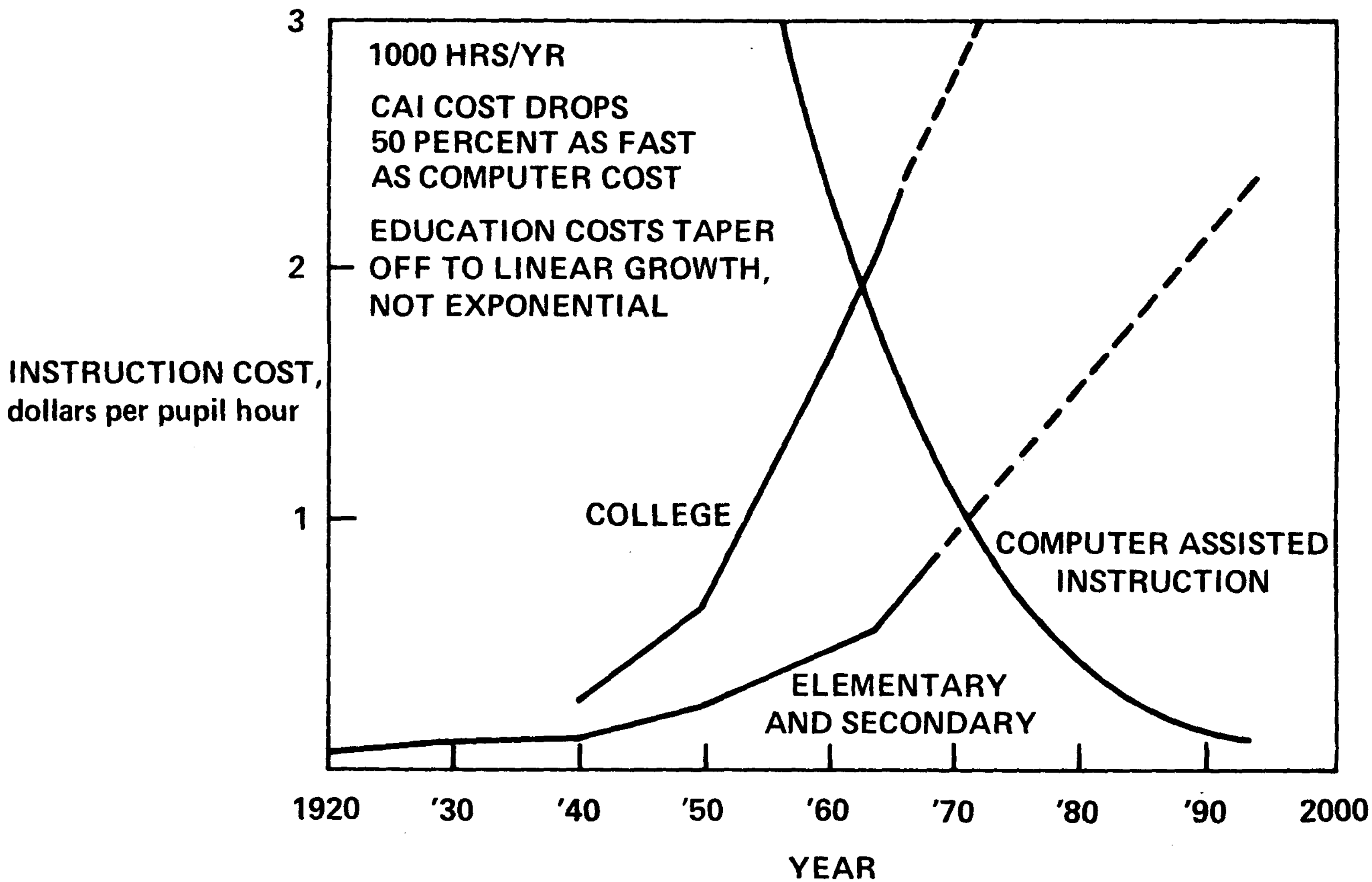
The graph on the facing page illustrates the kind of quantitative assessment used in the initial phases of the screening process. A service index or feasibility index was made for each of 259 of the initial services and an index of benefit was calculated, based on number of people affected, degree of benefit to each if implemented, etc. The evaluation represents the proportion of favorable responses to a checklist of criteria. Each service was plotted on the two dimensions of benefit and service "amenability". This space was partitioned into areas representing equal products of amenability, or feasibility, and degree of benefit. Thus services having the same product might either be highly beneficial services difficult to implement, or services not highly beneficial, but so easy to implement that they might still be considered, or a good balance between the two. This method was used because methods based strictly on monetary benefit tended to rule out many beneficial applications simply because they would not be attractive to the commercial sector; and by the same token, methods based on benefit to individuals tended to omit solid commercial applications. The high product concepts were retained for further analysis. The low product concepts were dropped and in some cases retained for later recombination into multipurpose concepts or "piggyback" concepts.

QUANTITATIVE ASSESSMENT EXAMPLE



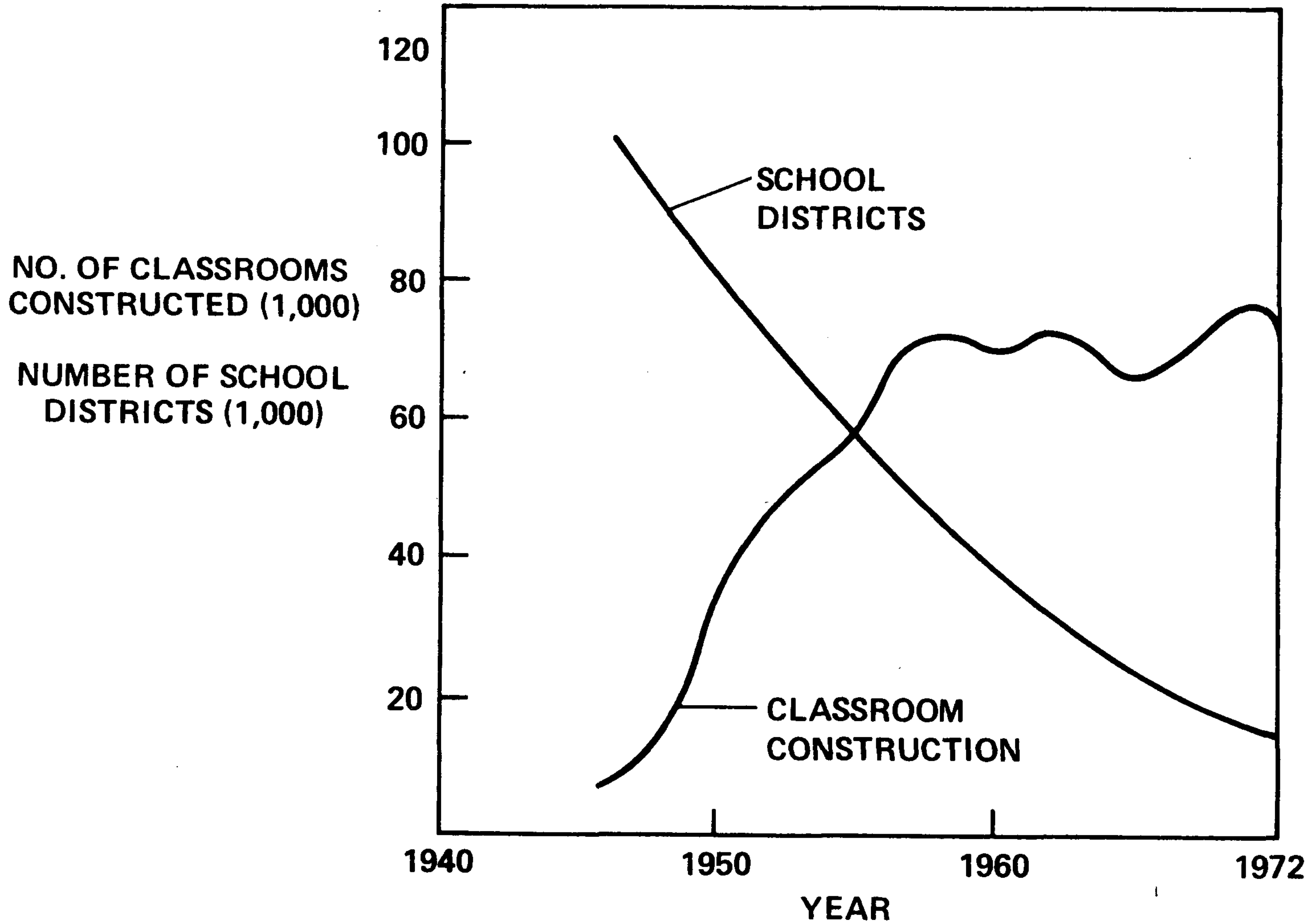
In the course of the evaluation it was frequently necessary to prepare tradeoffs that helped to clarify what assessment to give an individual factor. For example, whether INFOSATS will be moderately or extensively used in educational applications depends largely on trends in the educational sector. A "profile" of basic statistical data including tradeoffs of questionable factors was prepared in many areas. The curve presented is one such example. It shows that the costs of conventional methods of education have been rising and accelerating while the cost of computer assisted instruction, which should be a significant satellite user, has been dropping nearly as dramatically due to improved techniques and the rapid decrease of computer costs. While this cannot be used to prove conclusively that there will be a consequent rush to automate education, it does mean that the generally negative attitude of educators toward automation will be increasingly offset by cost pressures favoring automation. This leads to a higher estimate of the social acceptability of educational satellite applications than one would arrive at otherwise. Many such tradeoffs were performed in the course of the study.

EDUCATION COSTS



This illustration is similar to the last one in that it indicates the use of statistical time series data in supporting qualitative numerical assessments of such intangibles as social feasibility. The curve showing a decline in the number of school districts indicates an increasing willingness to centralize educational functions, at least on the administrative side. The curve on new classroom construction does not indicate a decline in new admissions, since it began to level off when new admissions were still rising, but rather represents the end of a trend of passing school bond issues. This has been interpreted by some authorities as the middle classes' "drawing the line" on the extent to which they would allow the costs of education, which they had previously perceived as almost an "unmitigated good", to rise. This reinforces the earlier point that regardless of the negative attitude toward automation in the educational sector, economic pressures may ultimately force significant electronic inroads into the traditional processes.

PUBLIC SCHOOL DISTRICTS AND NEW FACILITIES



The top services were further analyzed, subjected to more and more refined screening processes, and finally regrouped into a brief list of representative services. They are representative in the sense that the detailed cost and configuration analysis to which they would be subjected would not have to be done for each and every earlier service considered, but that the analysis of the final brief list would represent the analysis that would have been performed on the omitted services. In addition it was hoped that the analytical tools developed to perform the synthesis would be useful with only minimal modification if it were later decided to reinclude one of the omitted missions. The grouping therefore was done with respect to commonality, type of user, clustering of user locations, etc. For each category of service a detailed analysis was performed on about 3 to 6 variants or subcategories and in some cases, such as complete telecommunications services for remote areas (remote area telecommunications), many more variants were studied.

CONDENSED LIST - INFOSAT SERVICES

- LIKELY 1985
  - TELEVISION
  - REMOTE AREA TELECOMMUNICATIONS
  - DATA COLLECTION AND DISTRIBUTION
  - MOBILE COMMUNICATIONS
  - BIOMEDICAL COMMUNICATIONS
  - DOMESTIC WIDEBAND
- POSSIBLE 1985
  - CIVIC SAFETY
  - TRAVEL AND RECREATION
  - BUSINESS MANAGEMENT
- UNLIKELY 1985 (AS CONFIGURED)
  - EDUCATION AND INSTRUCTION TELEVISION

SYSTEM TRADEOFFS *

The next section of the report deals with the system analysis that was made on the selected, representative missions. Detailed technical and economic tradeoffs were performed on each candidate concept in the course of fitting user requirements to an equipment and network configuration. Whenever feasible the satellite concept was compared with a potential non-satellite network configuration. Although by this point users had usually already been extensively consulted, they were usually reconsulted at this stage after preliminary cost and performance figures had become available. In many cases the user requirements were changed when the cost implications of the initial requirements became known. For more than a few of the missions this process of iteration was repeated several times. The results were modified after each iteration and a process of convergence was instituted that in the case of certain missions proceeded rather far. The entire process permitted further identification of concepts that were especially cost effective.

SYSTEM TRADEOFFS

- DETAILED TRADEOFFS ON CANDIDATE CONCEPTS
- COMPARISON WITH NONSATELLITE NETWORKS
- RE-CONSULT USERS
- ITERATION
- REVISE, MODIFY RESULTS
- IDENTIFY COST EFFECTIVE REPRESENTATIVE CONCEPTS

An example of this process was the commercial TV distribution concept. It illustrates several points of interest in understanding the analysis. For $20.26 million per year commercial broadcast stations throughout the United States could receive a service by satellite that is now costing them approximately $60 to $70 million per year using the IXC microwave network. This figure, which was obtained using the computer synthesis model developed for this study, closely coincides with unpublished estimates made by such companies as Hughes, RCA, and COMSAT, and with the publicly released bid of Lockheed-MCI to the broadcasters. This and several other instances in which detailed estimates or actual bids have coincided with the results of the synthesis model are evidence of its accuracy at least as a planning tool.

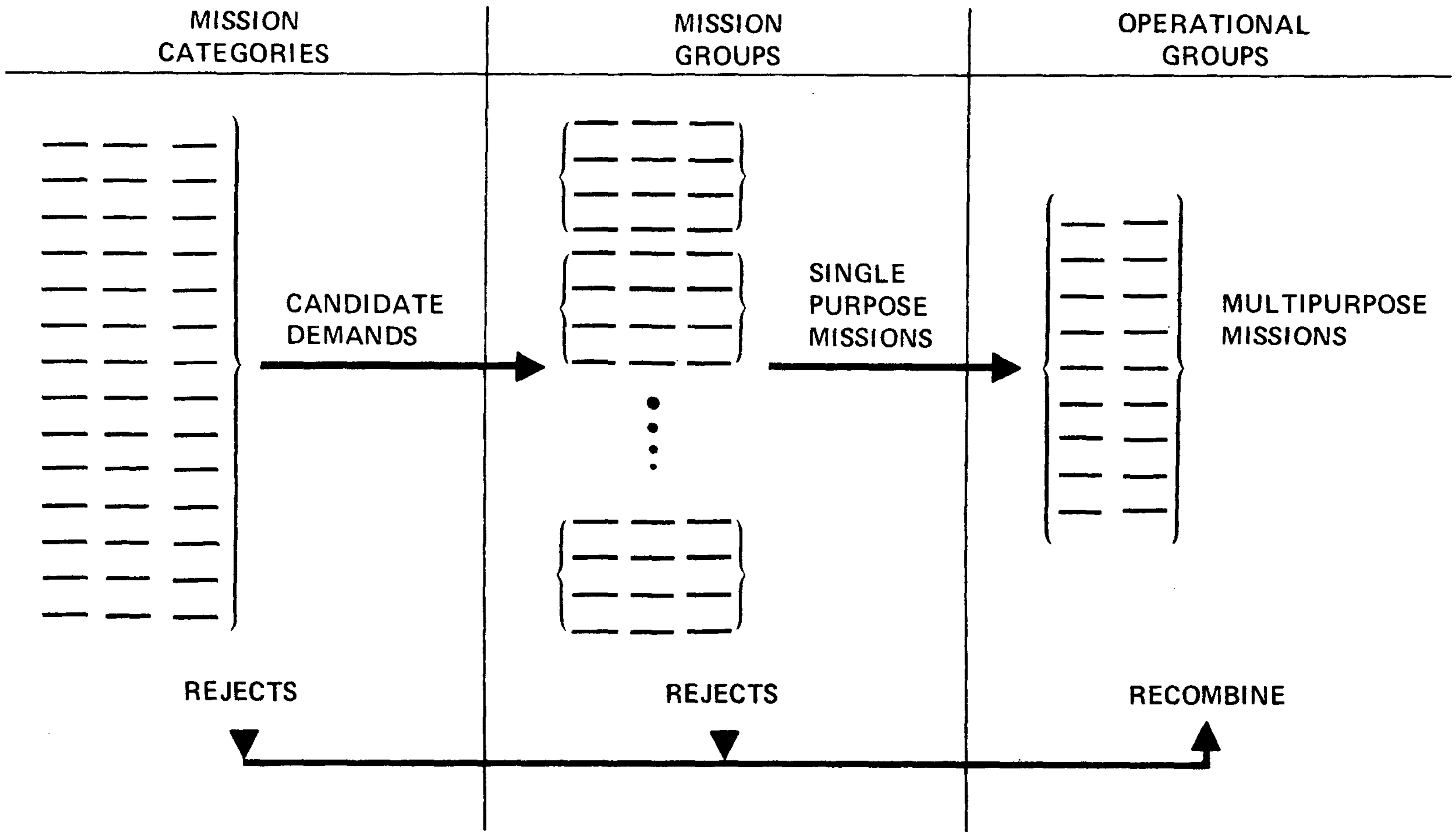
One of the reasons that we have concentrated on the unique beneficial applications of the satellite is that the introduction of a satellite to applications such as the present one might not provide a unique new service, but merely a cost saving to the broadcasters. How this benefit would be passed on to the ultimate user is problematical. Neither is it clear how the cost of writing off the existing IXC network, which would be superseded, would be passed on to the consumers of other telecommunications services.

SYSTEM ANALYSIS EXAMPLE
COMMERCIAL TV DISTRIBUTION COSTS

	NON-RECURRING	ACQUISITION	ANNUAL OPERATIONS	ANNUAL MAINTENANCE	TOTAL	TOTAL 10 YR ANNUALIZED
ORIGINATION FACILITIES	–	16.6	1.85	1.10	46.1	4.61
DESTINATION FACILITIES	–	12.2	1.61	.83	36.6	3.66
SATELLITES	41.35	31.13	–	–	72.48	7.25
LAUNCH VEHICLES	5.40	42.0	–	–	47.40	4.74
TOTAL SYSTEM	46.75	101.93	3.46	1.93	202.6	20.26

As previously mentioned, not all dedicated services could stand on their own. Therefore an analysis of multipurpose systems was undertaken. Single purpose, or dedicated, systems were synthesized into commonality systems based on like technology, like service, and compatible subsystems. An example is the combination of the law enforcement mission with credit card verification and a federal reserve network to take advantage of the common digital basis, common location of terminals, and basic similarity of the data bank response characteristic.

MULTIPURPOSE ANALYSIS



The example given shows that there are significant savings provided by the multipurpose combination of missions compared to the sum of the single purpose costs if only the space segment is considered. Unfortunately, however, it was not apparent how to achieve the same degree of commonality in the ground system so that the gains are essentially lost when total system costs are considered. In addition, even the gains in the space segment through commonality would create severe problems in rate making because of the difficulty of allocating costs to the separate services included. For example, it may be that credit cards, which experience only a modest saving in the multipurpose concept, are strongly cross-subsidizing the federal reserve system mission: Would it be fair to allocate charges based on weight, power, or cost of the piggyback mission, even though the cost was low only because it was using the economy of scale provided by the other mission? Such cross-subsidization may be useful, however, for public service missions--those that are so beneficial that their costs should be underwritten by another revenue producing mission.

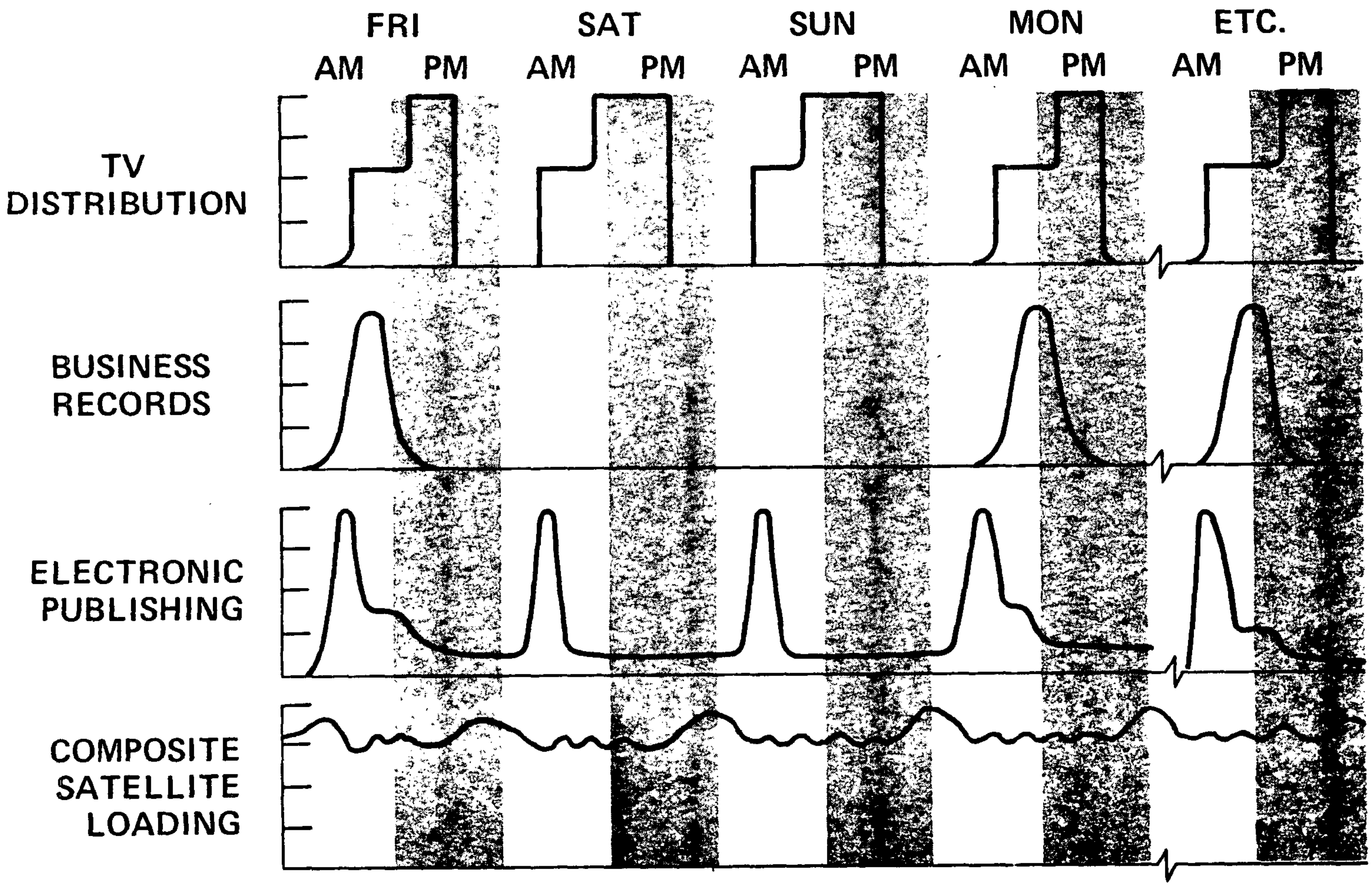
In summary, the brief experience here with multipurpose missions is that the objectives of individual programs are so compromised when attempting commonality missions, and the cost savings are so slight, that dedicated missions deserve the most emphasis.

MULTIPURPOSE ANALYSIS EXAMPLE

MISSION	COST IN MILLIONS OF DOLLARS			
	SPACE SEGMENT		TOTAL SYSTEM	
	SINGLE PURPOSE	MULTIPURPOSE	SINGLE	MULTI
LAW ENFORCEMENT	4.9	2.3	10.9	8.15
CREDIT CARDS	5.4	3.7	186.8	197.0
FEDERAL RESERVE SYSTEM	4.8	0.27	6.9	2.3
TOTAL	15.1	6.27	204.6	207

Another kind of "multipurpose" concept exploits the fact that the peaks of various services occur at different times. For example TV distribution reaches its peak during the evening prime time hours and on weekend afternoons, while business record transmission reaches a peak late in the business day in each time zone. If these services could be combined somehow their peaks might be averaged so that transponders would not have to be designed for such a severe peak to average traffic ratio, leading to poor utilization and overdesign. The facing figure illustrates how three such loading peaks can be smoothed into a composite satellite loading profile that is relatively level. This example illustrates a case in which the commonality would not be at the transponder level, since electronic publishing and business records would probably use transponders quite separate from the TV distribution transponders. But if all the transponders were integrated into a single spacecraft "bus" the advantage of commonality might be gained in terms of smooth satellite power and other requirements.

COMMONALITY ANALYSIS EXAMPLE



“MARKET ANALYSIS” *

The next two sections of the brochure discuss the market analysis in two parts: "Indications and Trends", which describes the time series and other data used to forecast the overall market potential; and "Market Factors", which describes the rationale for estimating the share of the market that may reasonably be expected for the satellite.

MARKET ANALYSIS

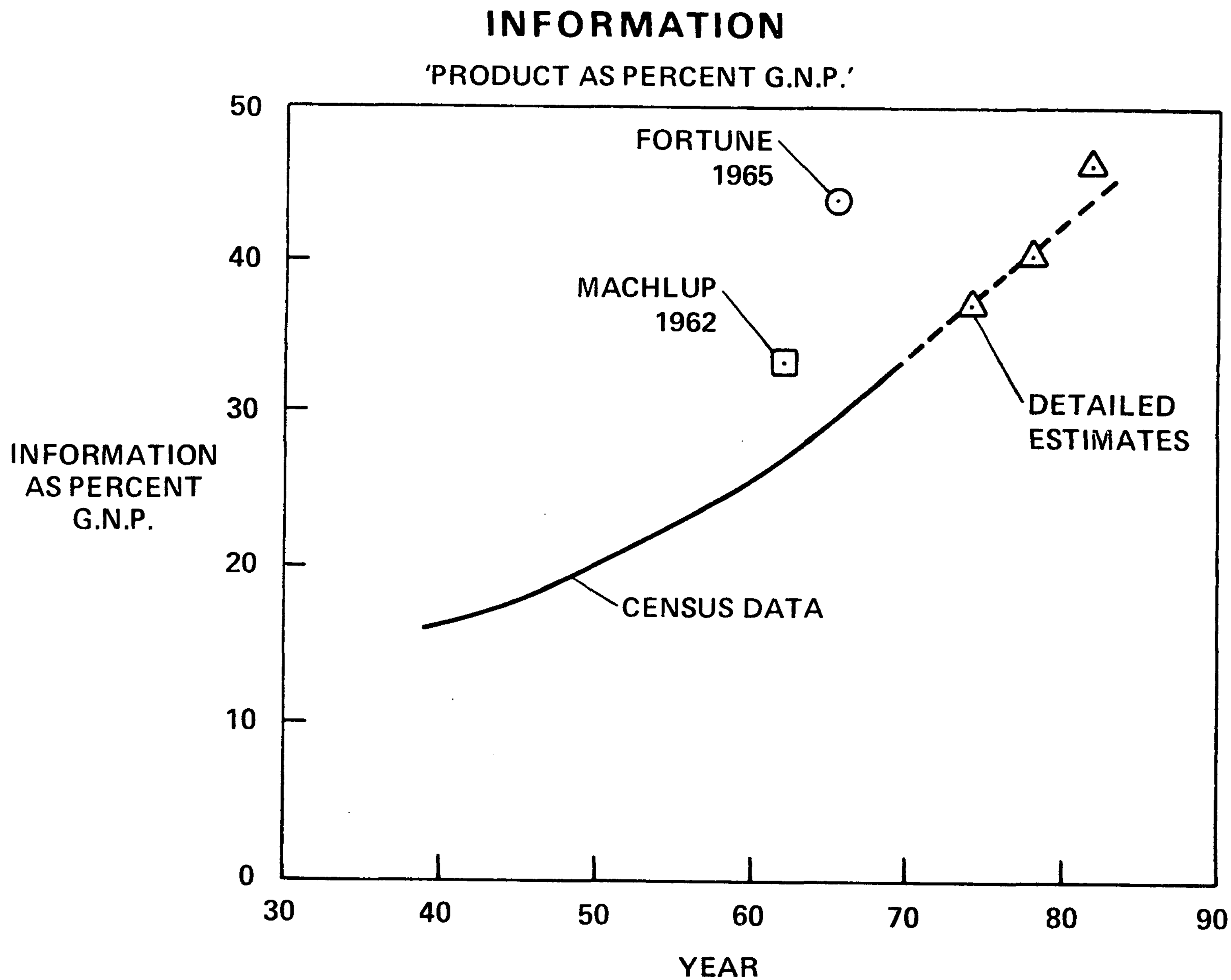
- INDICATIONS AND TRENDS
- MARKET FACTORS

This portion of the market analysis describes the striking changes taking place in the information transfer picture in the United States as a result of the trend to a service economy. It attempts to map the dimensions of the resulting information revolution and it outlines the kind of revenues to be expected in different media in this revolution.

INDICATIONS AND TRENDS

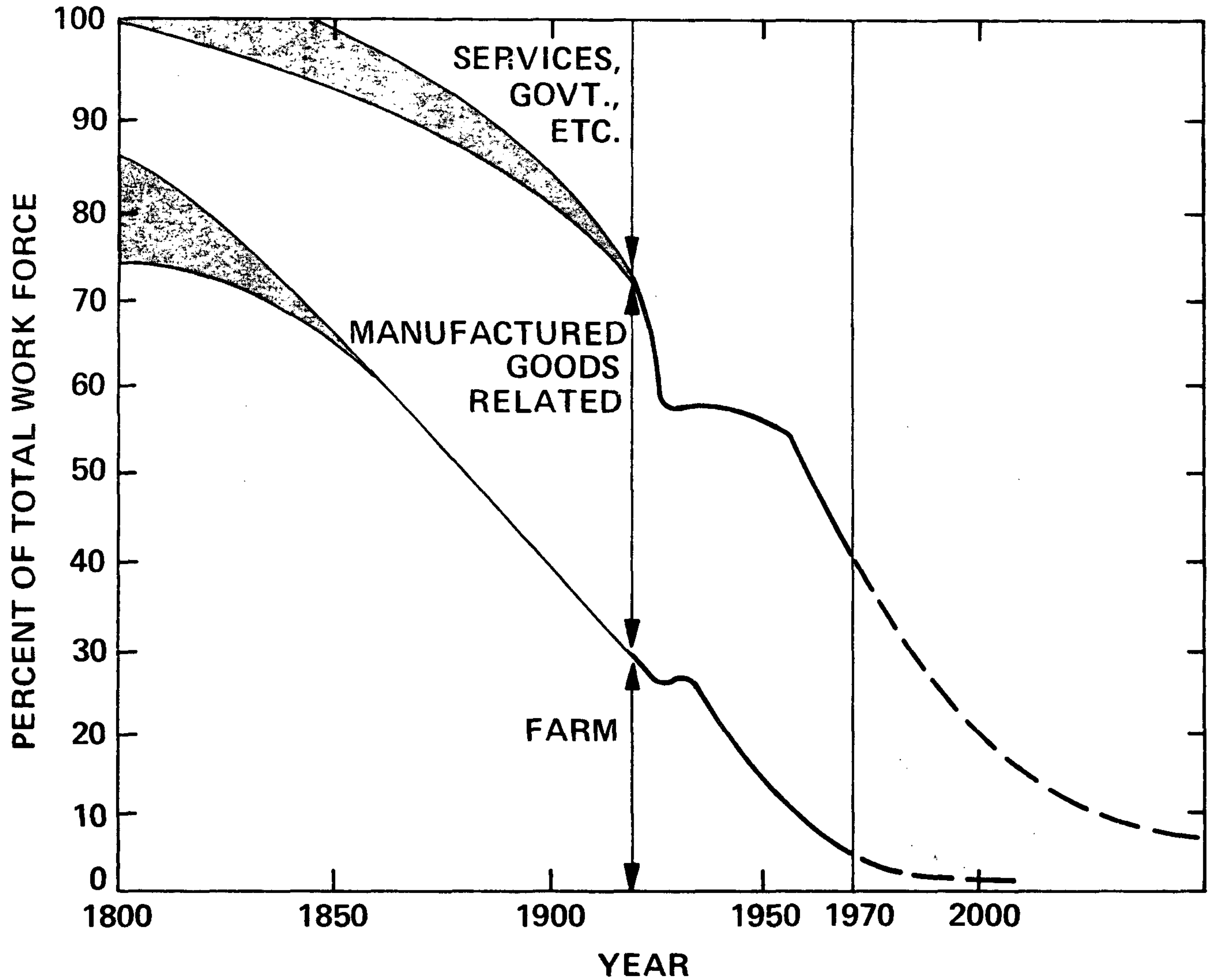
- INFORMATION PRODUCT
- SERVICE ECONOMY
- INFORMATION REVOLUTION
- COMPETING MEDIA
- NEW SERVICES
- FUTURE REVENUES

The purpose of this chart is to illustrate the rapid growth of information compared to the rest of the economy. Machlup in 1962 found that 32% of the economy was information transfer, and Fortune magazine updated his comprehensive study to find a figure of 42% in 1965. Machlup's methodology was used, together with Bureau of the Census data, to determine the corresponding percentages for the past 30 years and to make detailed (30 sector) estimates to 1980. The estimate is very conservative and did not use certain information-favoring corrections in the total GNP that were used by Machlup or Fortune in their estimates. It still illustrates the point, however, that this society is becoming increasingly involved in the transfer of information as compared to the transfer of energy or of goods. In fact, information is growing at a characteristic rate in which it doubles every 5 years compared to energy transfer, mass transfer, and goods production which double every 10 years.


INFORMATION
'PRODUCT AS PERCENT G.N.P.'
INFORMATION AS PERCENT G.N.P.
FORTUNE 1965
MACHLUP 1962
DETAILED ESTIMATES
CENSUS DATA
YEAR
50
40
30
20
10
0
30
40
50
60
70
80
90

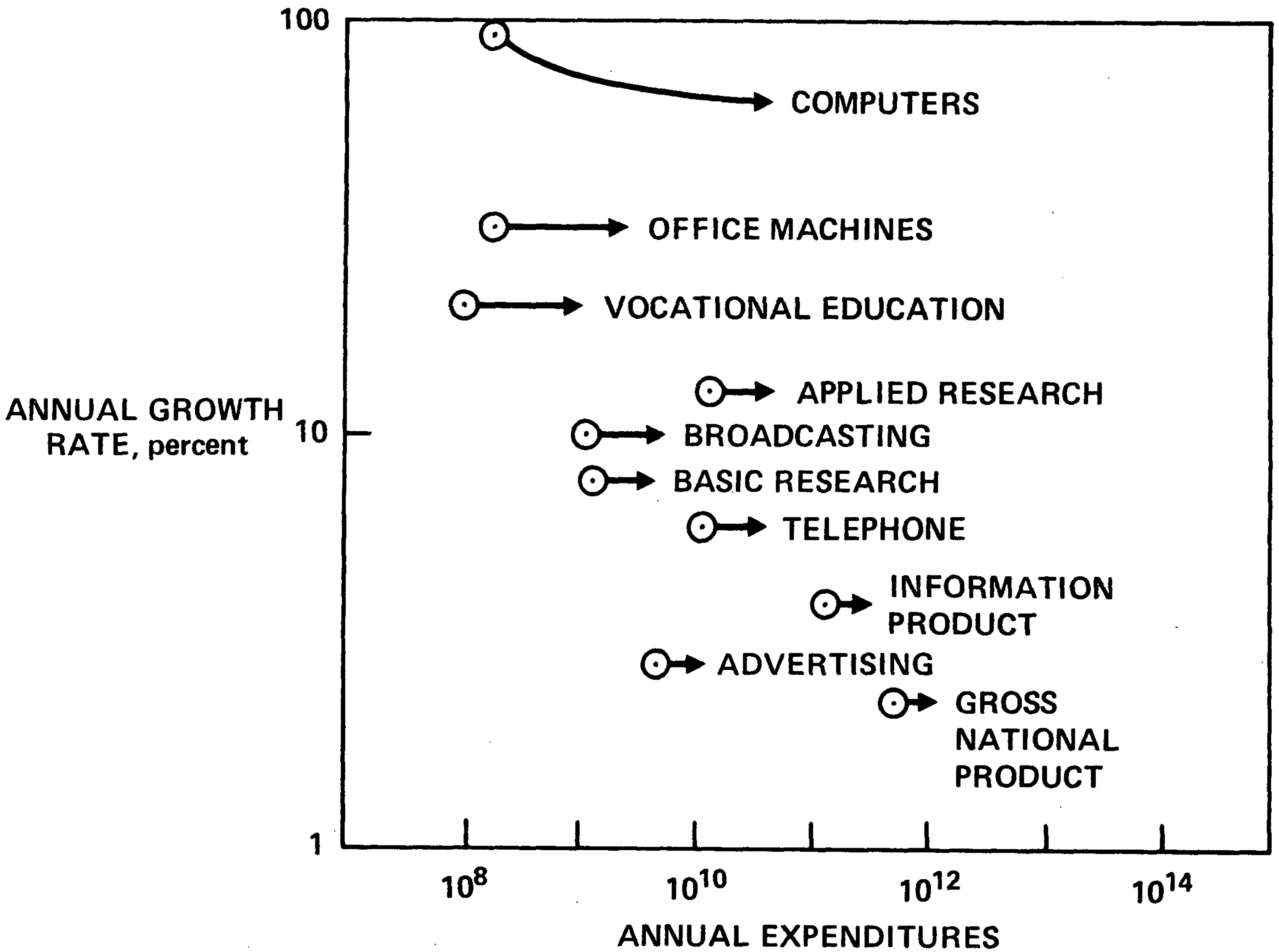
One of the reasons for the rapid growth of information transfer as an economic activity, shown on the previous chart, is the continuing long term trend away from an agriculture and manufacturing economy to a service economy. Services involve very little transfer of goods and energy and are very intensively involved in the transfer of information. Just as the productivity of the farming and manufacturing sectors were increased first by machinery and later by automation, the increases in productivity that will be needed by the service sector must come about largely through information transfer and computer augmentation of the human intellect. Fortunately electronic information transfer has traditionally been characterized by productivity increases on the order of 6% to 7% per year. Thus if overall productivity increase rates are to be maintained (as some economists seem to think essential), a much increased activity in applying electronic information handling techniques to the service sector will be mandatory.

WORK FORCE ENGAGED IN FARM, GOODS, AND SERVICES



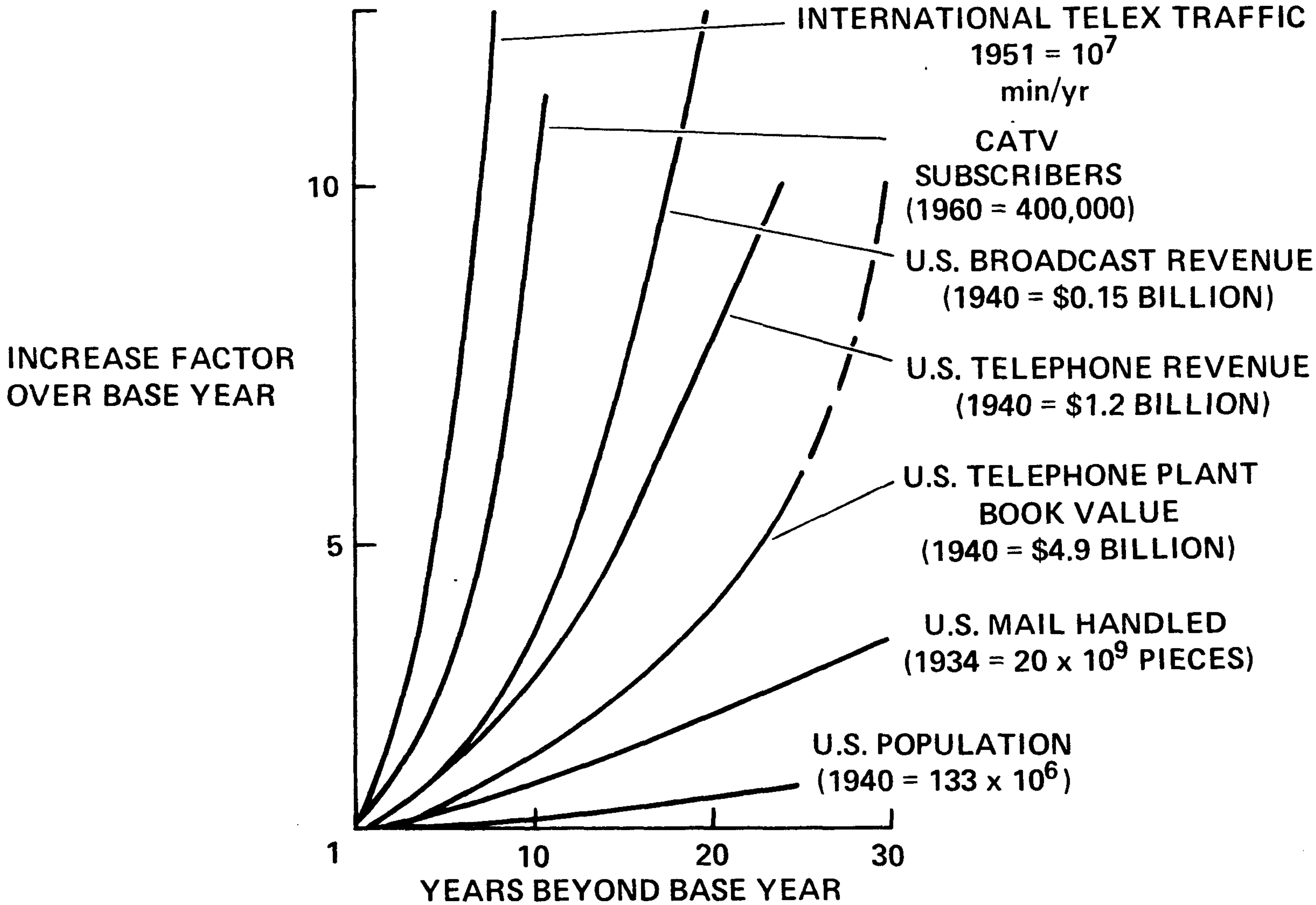
Several rapid to moderate growth sectors of the information transfer revolution are shown, with their value in 1958 and projected growth to date. This indicates how a small but rapidly growing item, such as computers, may by sheer force of growth become a significant national budget item within a decade. Thus in projecting future trends it becomes very important to project not only the large budget items but also the small rapid growth ones that may in time overwhelm the larger item.

INFORMATION REVOLUTION FORCES • 1958 – 1972



The facing curve clearly illustrates why the growth rates typical of information transfer give rise to the term "information explosion". Each sector mentioned has experienced rapid exponential growth. Two year doubling periods are common, and the average is 5 years. Although each of the most rapidly growing sectors ultimately folds over in the characteristic "S", or Gompertz curve, new sectors are continually "taking off" so that the composite curve of growth continues to increase at a rate of 10-12 percent per year. For example, since the chart was first prepared, the growth rate of Telex has slowed somewhat and Cable TV is probably the front runner in terms of growth. And yet the growth curve of Cable TV must soon begin to turn over after its rapid growth during the 70's brings it to saturation by the end of the decade. By that time there will likely be two or three other newcomers to the field that will be experiencing 50% per year growth rates. It is worth mentioning that many studies of telecommunications growth rates show them to increase exponentially through times of war as well as economic depression. A slight dip in the curve during a war is sure to be replaced by an equivalent period of more rapid increase--almost as if there were an actual deficit that must be made up.

TYPICAL EXPONENTIAL GROWTH CURVES RELEVANT TO INFORMATION TRANSFER

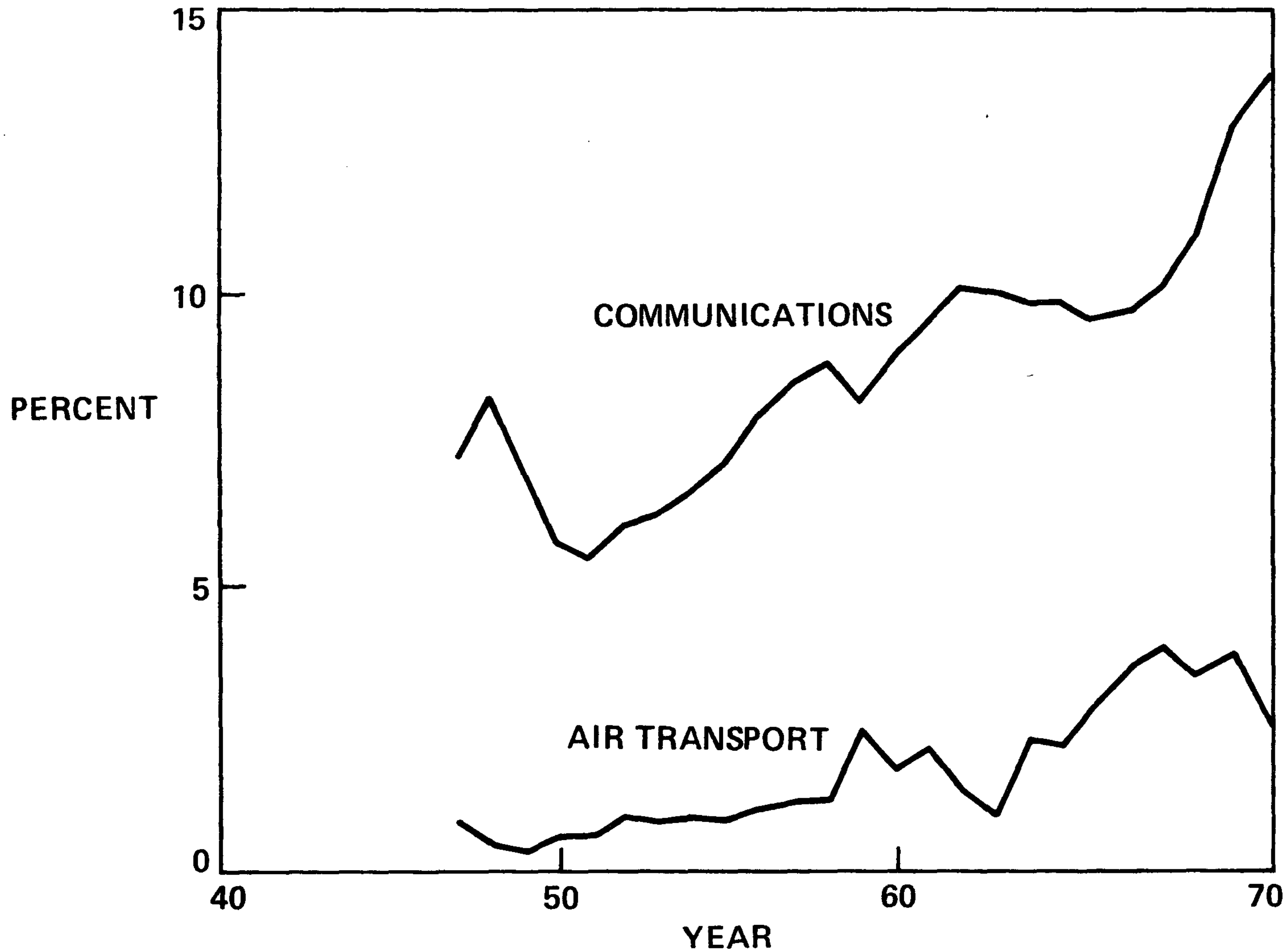


The facing graph shows that expenditures for new telecommunications plants are a large and rapidly growing portion of total business expenditures. These expenditures can be compared to those of air transport, for example, which are not only much smaller but are recently showing a decreasing trend. Ten billion dollars per year is spent on telephone plant alone. There has been a chronic inability to satisfy the demand for telecommunications with the rates of capital investment possible without going to excessive interest rates. Therefore we are justified in saying that telecommunications is capital-limited instead of demand-limited.

Another real limitation in the future on terrestrial communications systems is real estate along the cable right of way, since more and more of the telecommunications plant is going to be buried cable, waveguide, laser pipes, etc., instead of above-ground microwave. This is analogous to the future space systems. These will not be demand-limited either, but will be limited by the "real estate" of electrospace. More will be said of this subject later in this brochure.

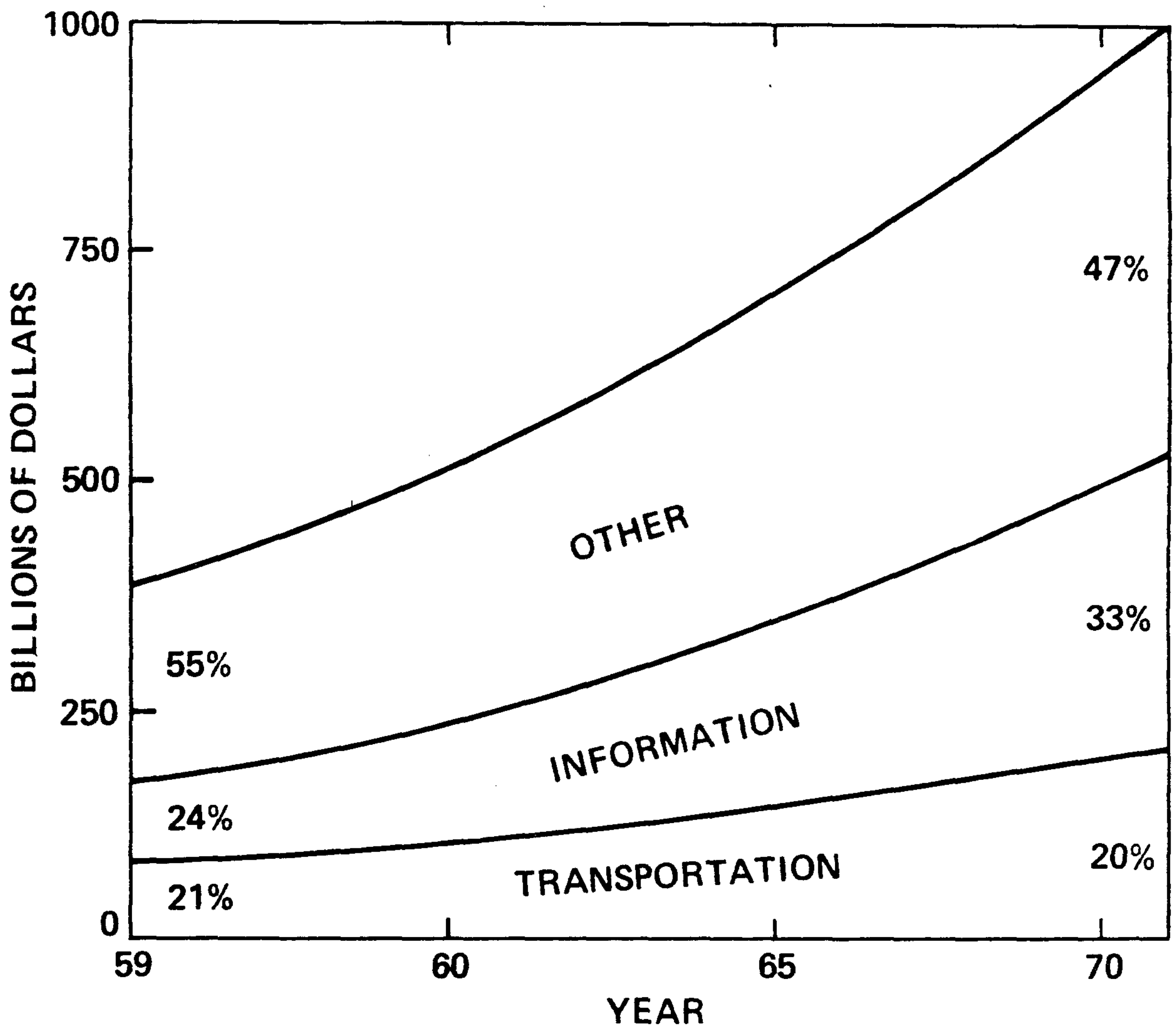
BUSINESS EXPENDITURES FOR NEW PLANT AND EQUIPMENT

PERCENT OF TOTAL



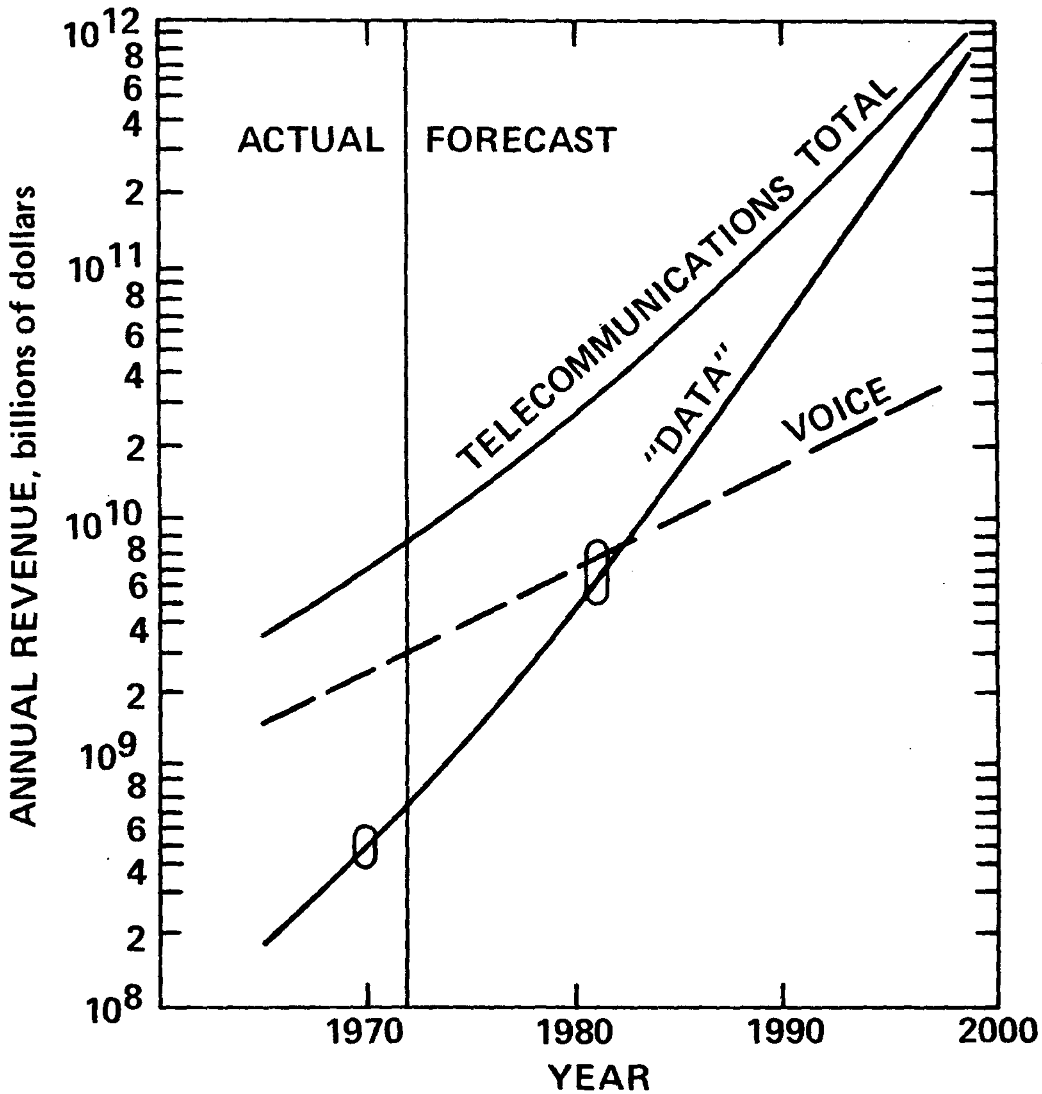
The facing chart shows that information has grown from 24% of the economy in 1960 to 33% of the economy in 1970 while transportation has remained an approximately constant percentage. The remaining economy factors have decreased from 55% to 47%. Much of the information sector consists of informal education and education related expenditures.

COMPONENTS OF GROSS NATIONAL PRODUCT



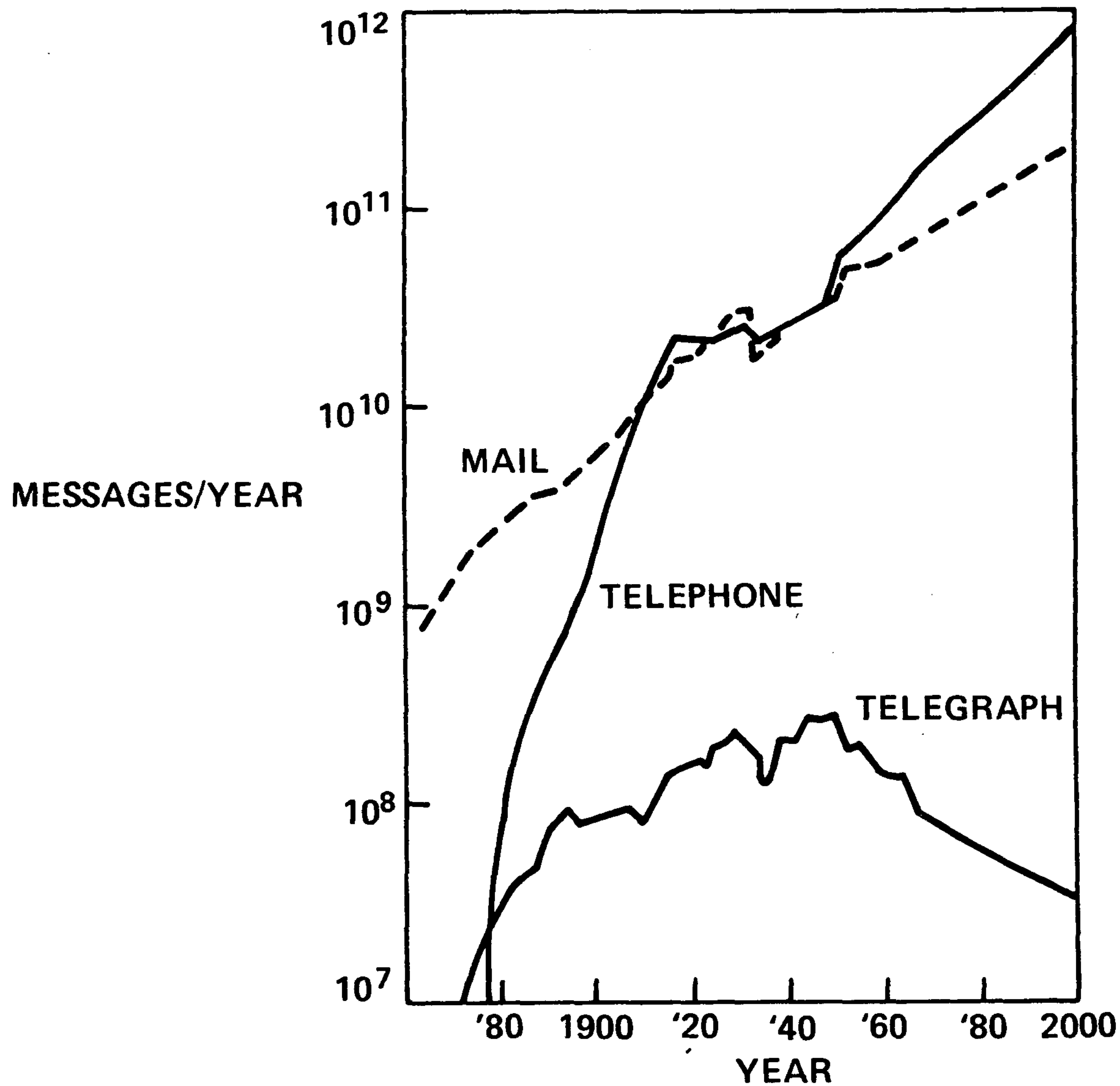
At present most telecommunications revenue is from human communications. Although human communications, particularly long distance, is growing at a very rapid rate, long distance data transmission is growing much faster, and many experts predict that the two will be equal in revenue in the early to mid 1980's. Data communications are in the rapidly accelerating phase and no slowing down, let alone turning over of the demand curve, is yet forseeable. This trend stimulates--and is stimulated by--the rapid growth of computers shown on a previous chart, and represents an entirely new trend, the "computer communications revolution". This revolution has caught the telecommunications industry largely by surprise and the large investments that are required to keep pace with the demand will seriously modify the traditional ways of doing telecommunications business. Foreseen are many regulatory changes favorable to entrepreneurship and open competition.

LONG DISTANCE REVENUE



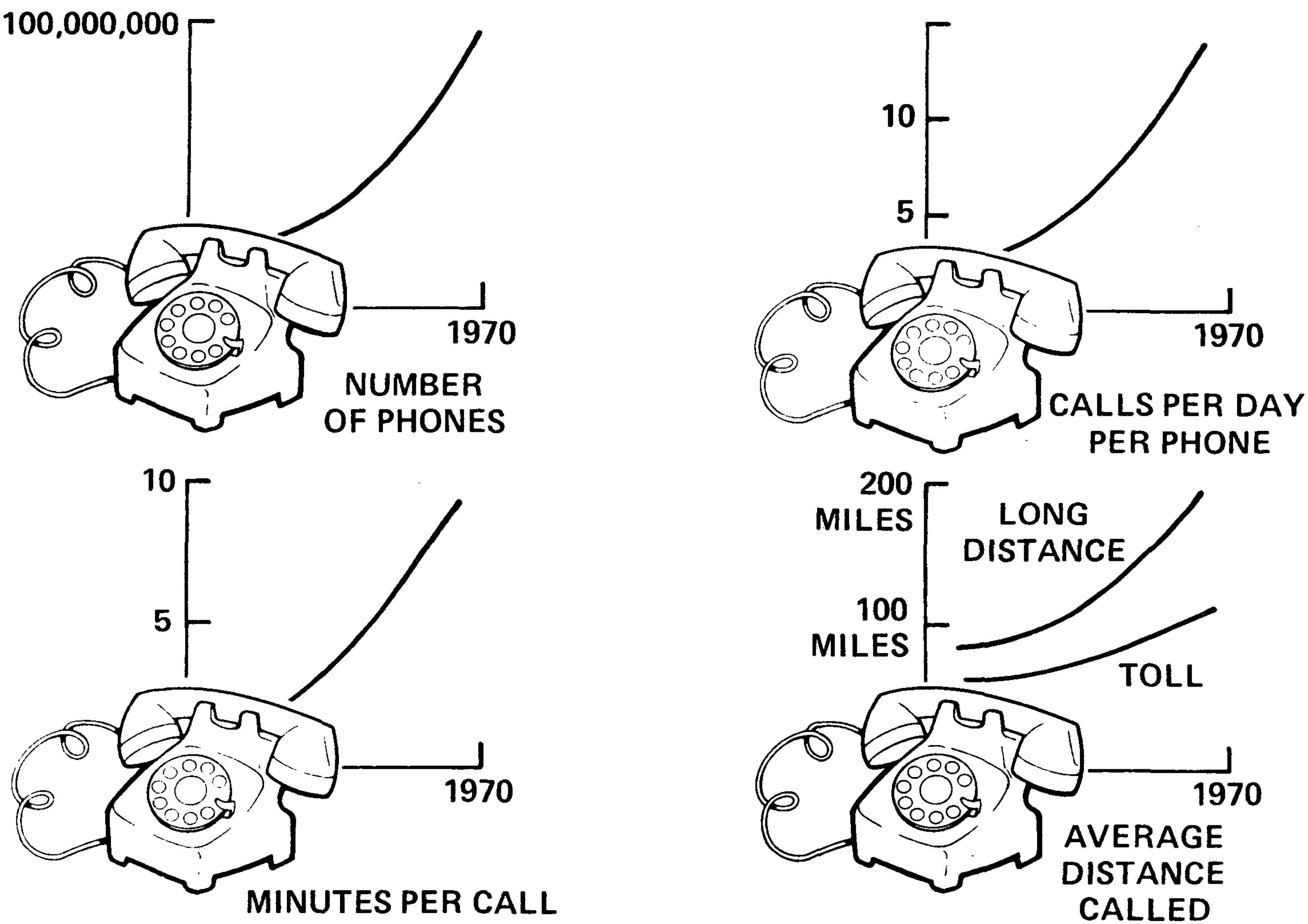
This curve indicates the three major ways of transmitting messages over the past century. It begins with mail, which had already reached a steady state growth rate by the turn of the century, and which began a "competition phase" with telegraph at about the same time. The telephone came into being in the late 1870's and almost immediately surpassed telegraph through its greater convenience. By the 1920's, with the advent of long distance communications, it was competing even with mail as the prime message transmission medium. By the beginning of the 60's the great annual productivity increase of the telecommunications industry had kept the prices so low relative to the price of mail transmission, and the relative convenience and delivery schedules remained so favorable, that business and personal communications habits had changed completely to favor the telephone as a medium of transmission. The competition now appears decided, with telegraph traffic slowly declining, mail growing at its century old rate, and telephonic communications skyrocketing at growth rates of 10% to 20% depending on the distance of the transmission.

COMMUNICATIONS TREND



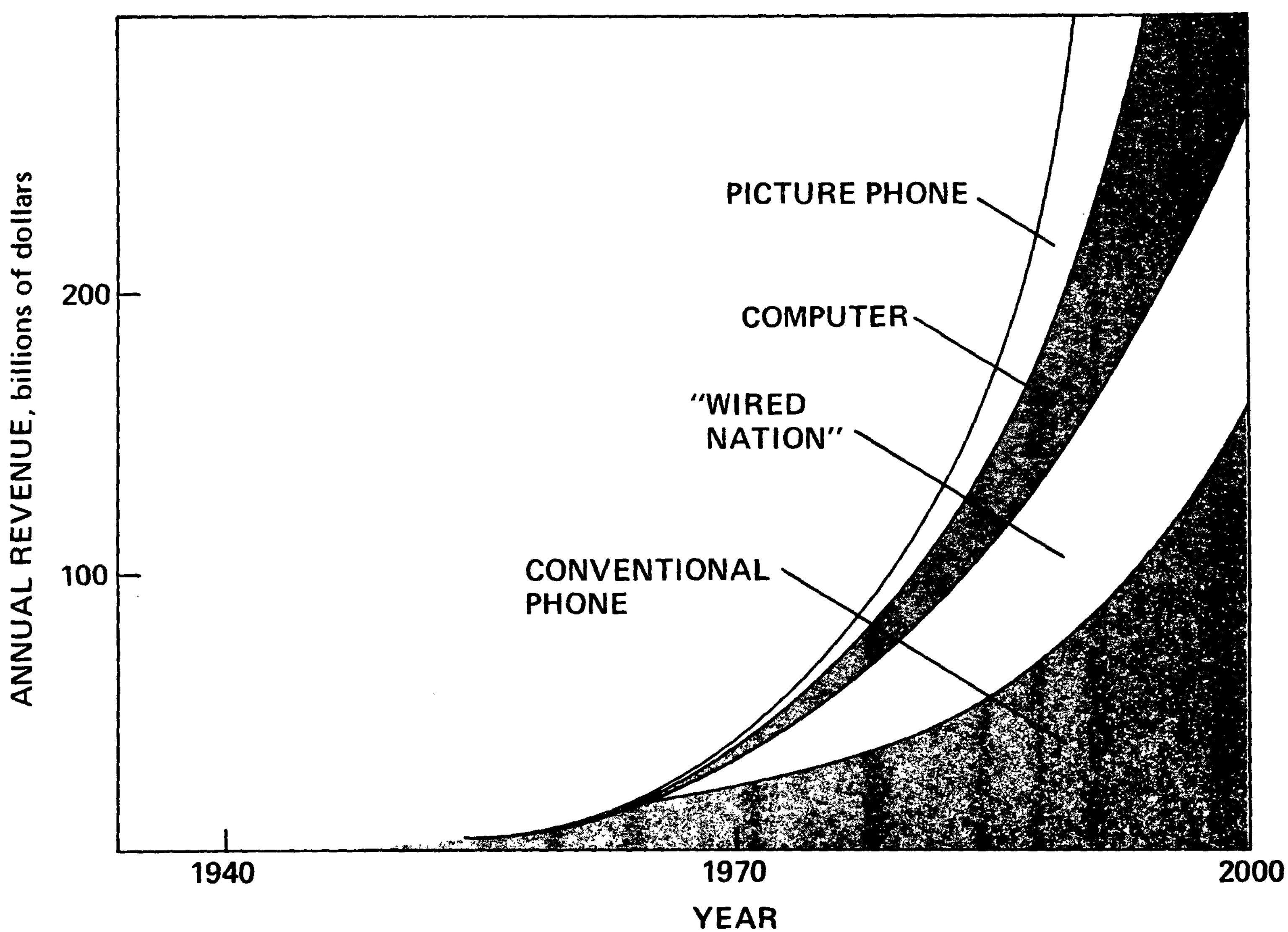
The backbone of the entire communications revolution is still, and will remain for some time, the century old telephone industry. In spite of its long history of rapid growth it is still very much alive and growing rapidly. The number of telephones has increased rapidly in the last decade and now exceeds 100 million. The number of calls per day per telephone has continued to grow and is now about 8 to 10. The number of minutes per call has doubled during the past decade--even more so for long distance calls. The average distance called has increased rapidly, with the percentage of calls over 500 miles, for example, increasing 50 percent during the past decade. Because the call duration is beginning to depart from century old assumptions as to length, the number of circuits required for a given number of subscribers is increasing significantly. In some areas such as Palo Alto, California, which uses telephone circuits heavily for computer time-sharing, the new usage patterns are so different from the past that traditional methods of planning circuits are practically impossible.

TELEPHONE REVOLUTION ACCELERATES



As we have mentioned, conventional telephones, although perhaps used in extremely novel new ways, will continue to be the mainstay of telecommunications relatively far into the future. The facing graph shows a relatively conservative estimate of the telecommunications industry revenues to the year 2000. Conventional phone will continue to increase, but wired nation applications such as on-demand news, entertainment, and computerized information banks will grow much more rapidly; computer transmissions will increase dramatically, and even such services as picturephone will grow into an important sector as satellite circuits become available for long distance use and as the presently prohibitive costs begin to diminish.

FUTURE TELECOMMUNICATIONS REVENUE



The next section discusses the INFOSAT share of the revolution in information transfer. It will describe the effect of distance and national policy on growth of telecommunications; the historical expenditures on INFOSATS including a modest projection of future expenditures; some of the traffic factors affecting the market; the relative shares of the expenditures represented by the satellite segment as opposed to the ground segment of a total INFOSAT system; and some speculations on the U.S. and world market share of INFOSATS.

MARKET FACTORS

- INFOSAT MARKET SHARE
- NATIONAL POLICY VS. GROWTH
- INFOSAT EXPENDITURES
- TRAFFIC FACTORS
    - POPULATION PRODUCT LAW
    - DISTANCE
- SATELLITE VS. TERRESTRIAL SHARE
- NORTH AMERICAN INFOSAT MARKET
- WORLD (LESS N.A.) INFOSAT MARKET
- TOTAL WORLD MARKET

We have already shown that the total U.S. information product is currently about 350 billion. This share is rising and probably the future share it represents will be sensitive mainly to public policy rather than to specific stimulation of demand. Not all of this market is suitable for satellite application because a large, but decreasing, share of information transfer takes place over such short distances that a satellite would not be useful. As we will show in a later curve the satellite potential* share is now 10-20 percent growing to perhaps 50-70 percent by 1990. Competition from the terrestrial sector will keep the effective share much lower than this, however. But even if the share is as large as shown here, it is very likely that there is insufficient spectrum/orbit resource to support more than a \$3 to \$5 billion domestic satellite industry. This problem is compounded by the fact that the space segment is becoming a smaller and smaller part of the expenditures for a given space communications system. The current domestic satellite proposals therefore probably represent a substantial part of the total potential information transfer market. If for example the Government is assumed to be responsible for the intelligent planning of the directions this development should take in the public interest, and if it is agreed that perhaps no more than 10 percent of the market should be thus allocated, then a bound of something like \$100 million to \$300 million is perhaps set on the right amount to spend on R&D.

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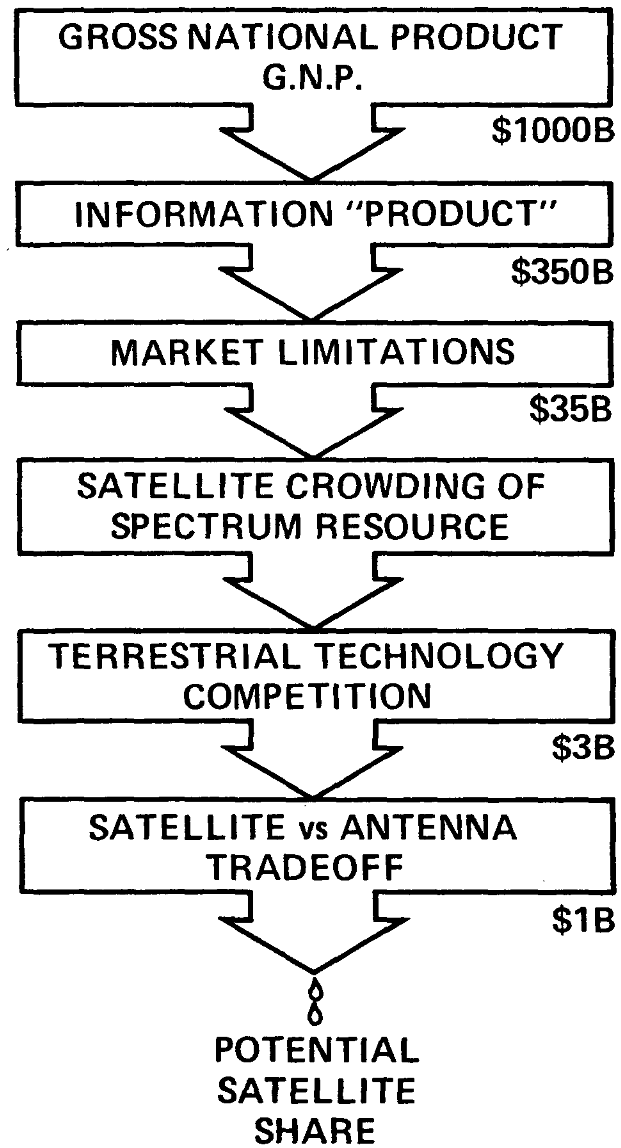
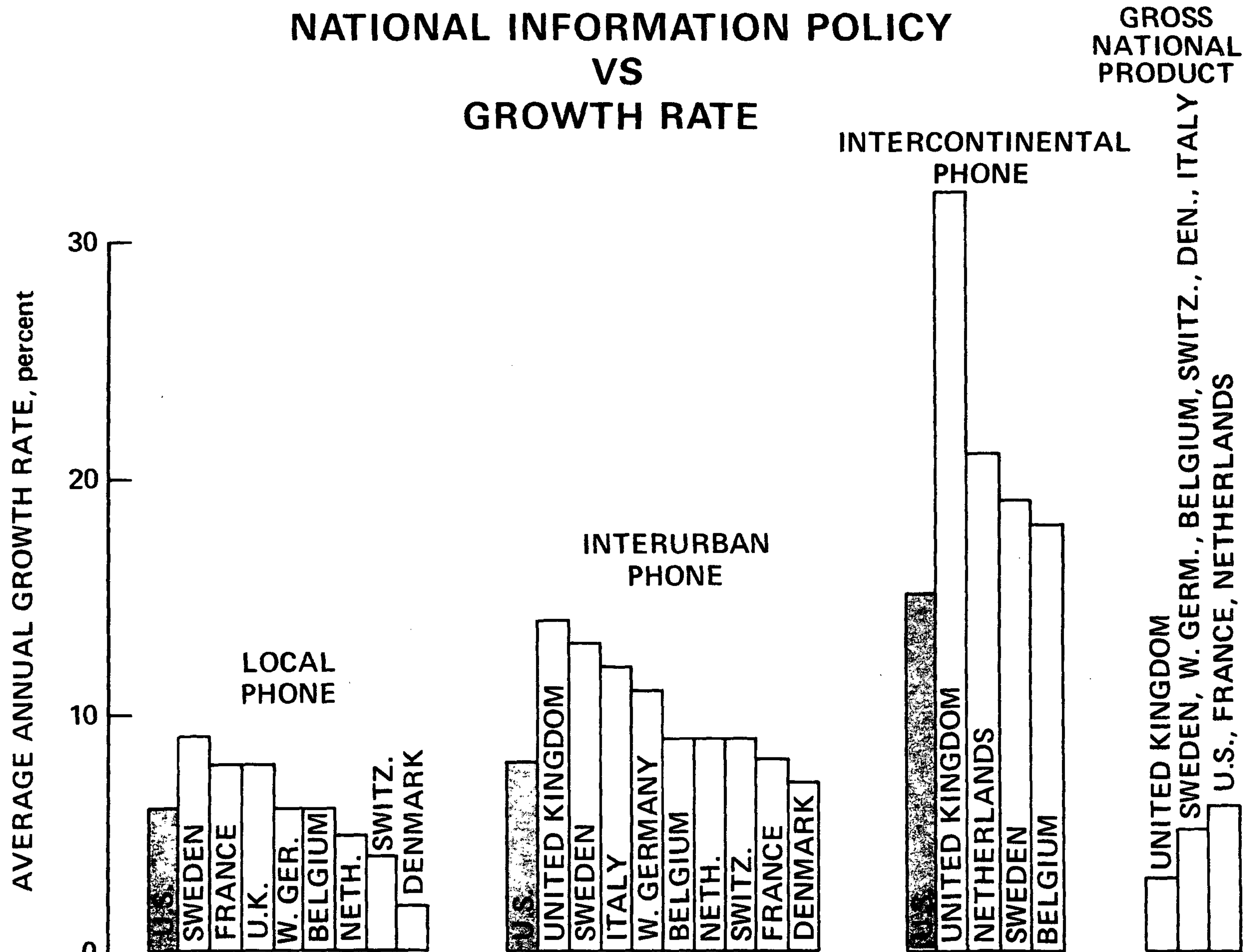
* i.e., ignoring competition

POTENTIAL SATELLITE MARKET SHARE

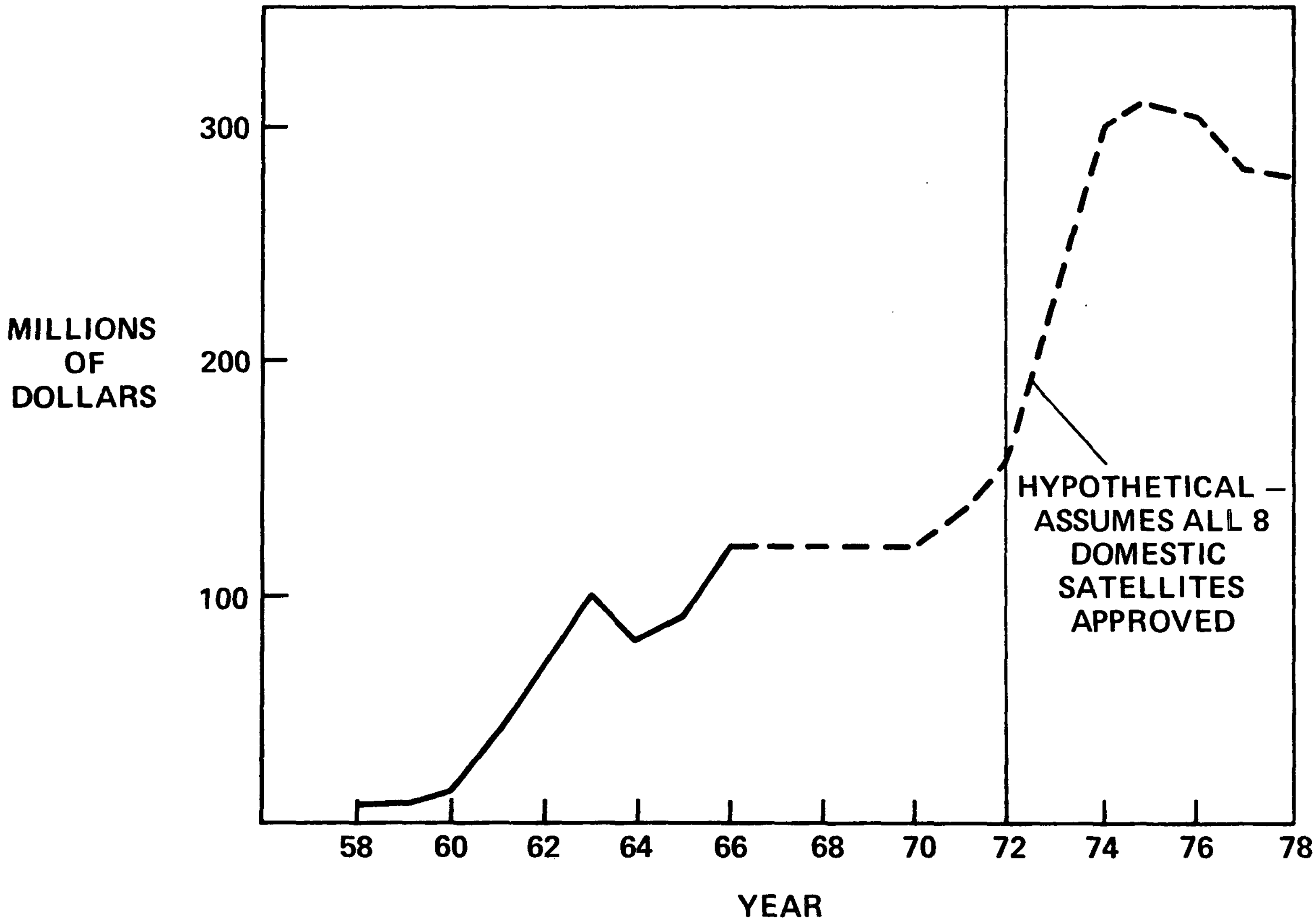


This curve shows the growth rate observed in administrations of various other nations for several distance classes of telephone service. It clearly shows that growth rate is much higher on the longer distance classes of telecommunications. It also shows that the United States is not at the forefront in growth of international telephone traffic and that other nations are perhaps more aggressive. That an aggressive administration can dramatically affect long term growth rates in telecommunications is most clearly shown in the case of the United Kingdom, which is showing impressive gains in telecommunications growth at all distances, particularly the longer distances, even though it has a lower GNP growth rate than the United States or the other countries compared here. The purpose of the curve is to show the kind of gains that could be made in the United States if certain changes were made in national telecommunications policy and regulatory procedures to encourage the industry to promote and keep pace with the demand that is ultimately possible.


NATIONAL INFORMATION POLICY
VS
GROWTH RATE
AVERAGE ANNUAL GROWTH RATE, percent
0
10
20
30
LOCAL PHONE
U.S.
SWEDEN
FRANCE
U.K.
W. GER.
BELGIUM
NETH.
SWITZ.
DENMARK
INTERURBAN PHONE
U.S.
UNITED KINGDOM
SWEDEN
ITALY
W. GERMANY
BELGIUM
NETH.
SWITZ.
FRANCE
DENMARK
INTERCONTINENTAL PHONE
U.S.
UNITED KINGDOM
NETHERLANDS
SWEDEN
BELGIUM
GROSS NATIONAL PRODUCT
UNITED KINGDOM
SWEDEN, W. GERM., BELGIUM, SWITZ., DEN., ITALY
U.S., FRANCE, NETHERLANDS

Compared even to the conservative estimates of the domestic market potential for INFOSATS that we have discussed, the actual market performance has been rather meager, as the facing curve shows. The eight pending domestic satellite applications, if approved and the systems actually put into operation, would more than double the expenditures on INFOSATS in this country. The growth has, of course, been seriously impeded by complex questions of national policy that must be resolved before the potential can be realized.

COMMUNICATIONS SATELLITE EXPENDITURES



Information transfer traffic behaves as if a relatively constant proportion of all possible fixed interconnections between terminals were always in fact made. That is, to a good approximation the traffic between city A and city B is a constant times the population of A times the population of B.* The practical effect of this is that the bulk of the traffic will always be between pairs of the largest population centers. Since this kind of traffic can be transmitted in the future using armored cable, waveguides, etc., the bulk of the traffic will probably never be available to communications satellites, because bulk information pipelines such as these can transmit information much cheaper than any foreseeable satellite. Therefore, presumably, if it is insisted that the satellites be used for point to point trunking, the satellite will always have to restrict itself to the lower density traffic links and the remoter locations far from the nationwide high-density grid. This point is important but is not always adequately appreciated by the satellite enthusiast.

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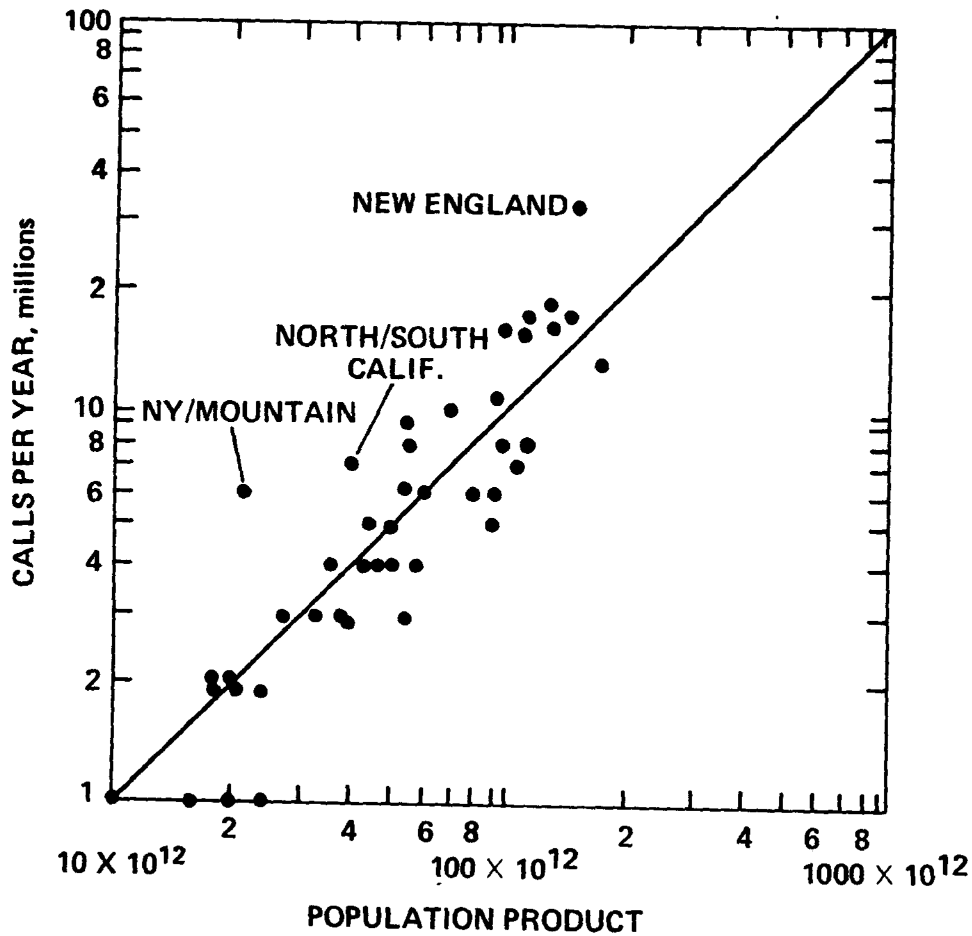
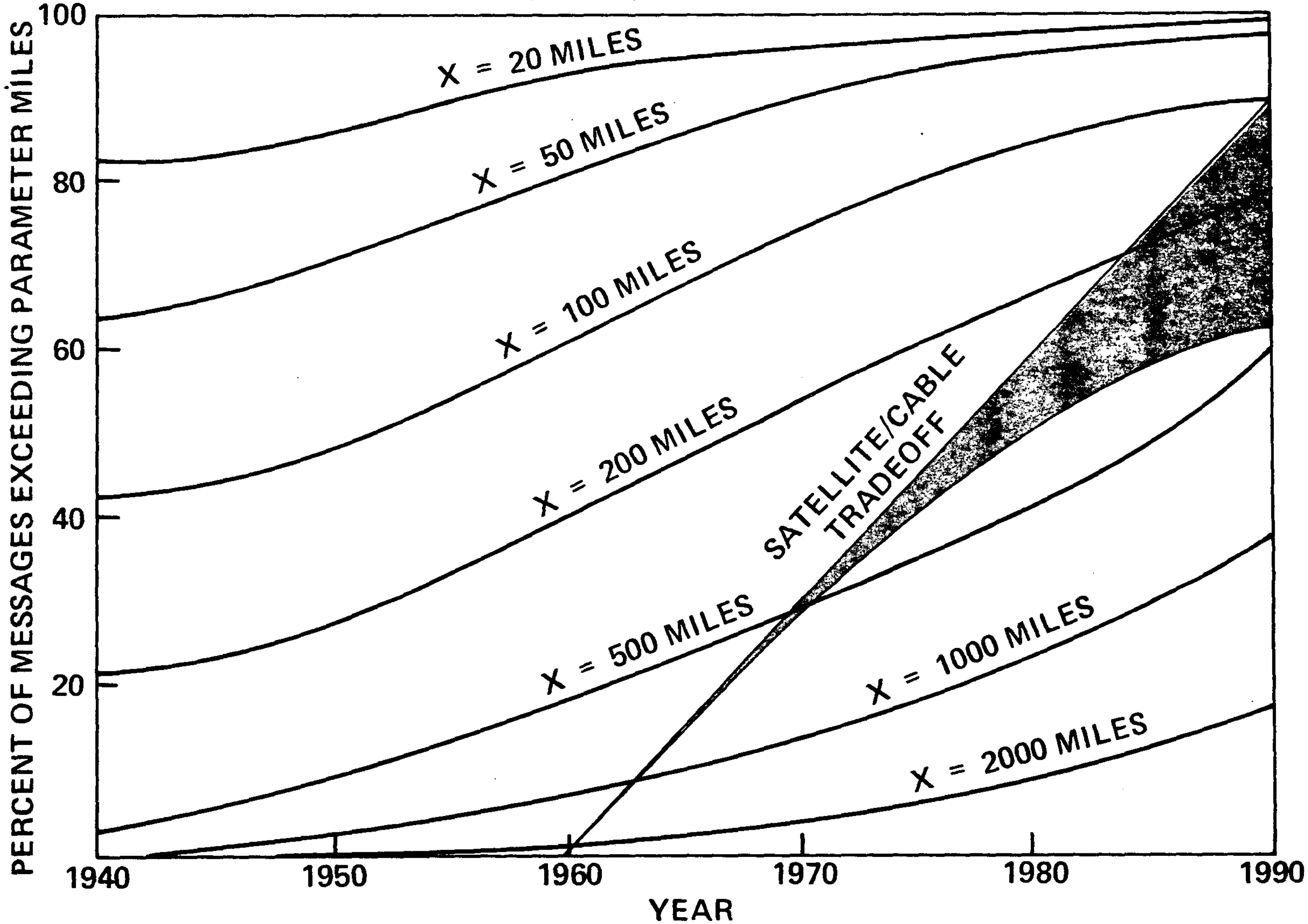
* Sometimes it is desirable to insert an inverse distance term. In the facing graph, Nij inter-regional toll calls, in millions/year, are plotted against Kij, the product of telephones in region i times telephones in region j for 45 inter-regional U.S. links. The formula $N_{ij} = 10^{-7} K_{ij}$ gives a good fit.

TRAFFIC PROJECTION FACTORS



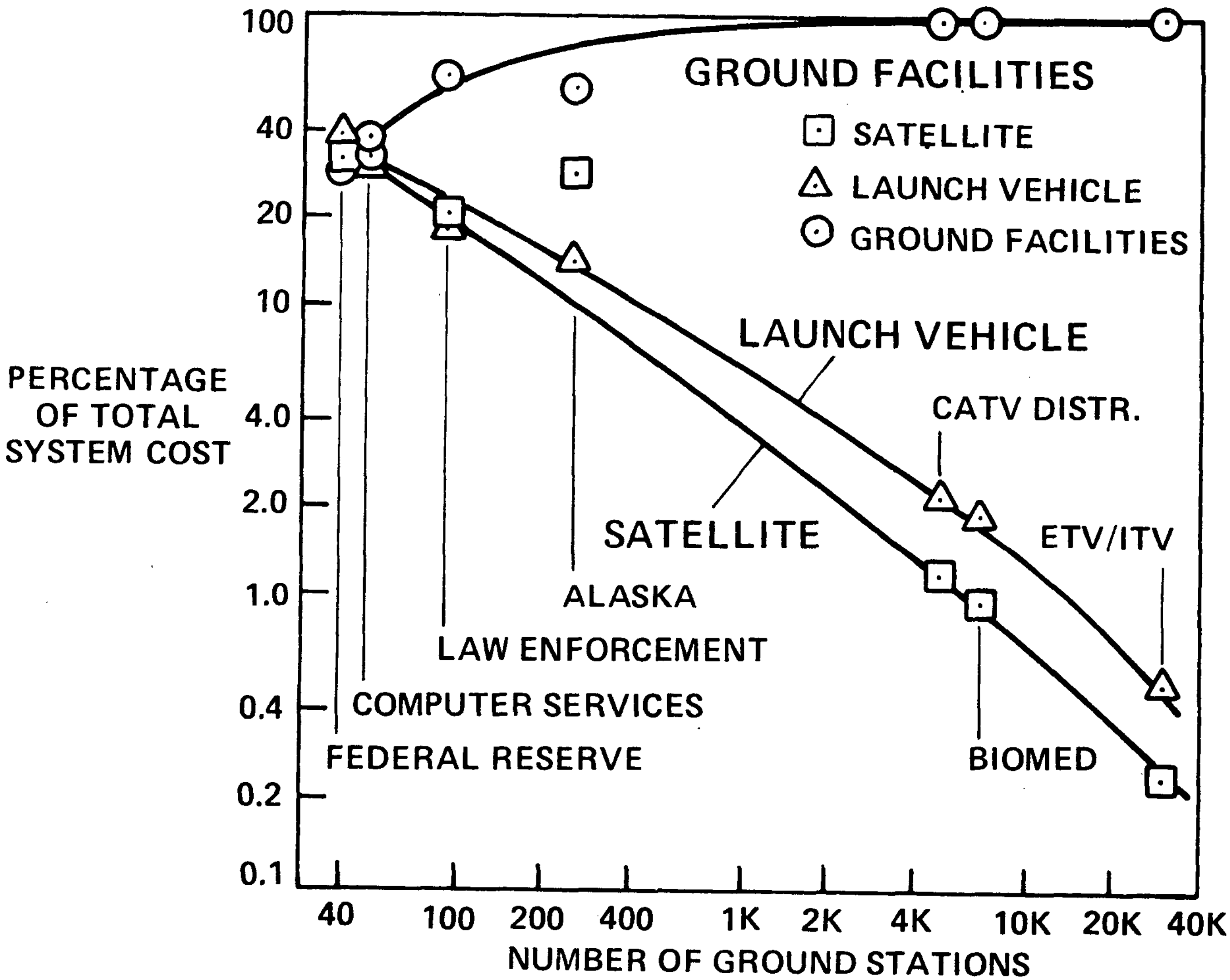
This chart illustrates several points. First, traffic has declined with distance in the past, primarily because the cost was traditionally proportionate to distance and an essentially inverse relationship existed between traffic and cost. But as has been briefly mentioned previously, there is a strong trend to longer distance calling. This was apparent from the curve shown earlier indicating that longer distance communication was growing much faster than local service. The facing curve shows that for any given distance the percentage of calls exceeding that distance is increasing rapidly. This trend and its extension should be immensely favorable to the communications satellite, since the cost of satellite communication is essentially independent of distance. Thus there is what might be called a breakpoint between satellite communications on the one hand, and cable or microwave communications on the other. This breakpoint varies in distance as the total cost of satellites declines over the years and as the cost per mile of cables declines at a different rate over the years. The approximate breakeven point tradeoff is crossplotted on the facing curve; if the crossplotted curve is read directly it gives the approximate percentage of messages suitable for satellite transmission versus year. This number could even be multiplied on a year to year basis by the total message traffic curve to produce a curve of potential satellite message traffic versus year.

TREND TO LONGER DISTANCE CALLS FAVORS SATELLITE



The curves on the illustration on the facing page illustrate the empirical fact that the larger the number of terminals in an INFOSAT system the smaller is the percentage of the total system cost represented by the satellite. Several systems studied are plotted to show the relative percentages represented by launch vehicle, satellite, and ground facilities. It might be inferred that the cost of the satellite would be in some way proportional to the number of stations it must support, and that is indeed true. But the cost of the satellite, because of its sharp economies of scale, does not scale up directly with the number of stations supported. Thus in optimal systems, the satellite becomes overwhelmed by the linearly increasing terminal costs. This simple fact reduces the total market potential of satellites considerably.

DISTRIBUTION OF SYSTEM COSTS FOR REPRESENTATIVE MISSIONS



The potential domestic information transfer market is shown to be approximately equal to 100 INFOSATS of the Intelsat 4 class* at the present time which will grow rapidly to 600 "Intelsats" by 1990. At the same time the current geosynchronous orbit limit is shown to be approximately 50 Intelsat 4's with a possibility for extension through very intensive technology development to about 100 or 200 by 1990. Therefore it is easily seen that even if the obvious fact of competition from the terrestrial sector is ignored, the future development of communication satellites will face the limit imposed by "electrospace", i.e. the combined effects of the limited geosynchronous arc and the spectrum available at each point on that arc.

As an additional bit of perspective the long-haul telephone traffic of California alone is also plotted. It can be seen that if the 18 percent per year steady growth rate of California long-haul telephone traffic is continued until 1990 it alone will exceed even the most optimistic estimate of the traffic handling capability of geosynchronous orbit.

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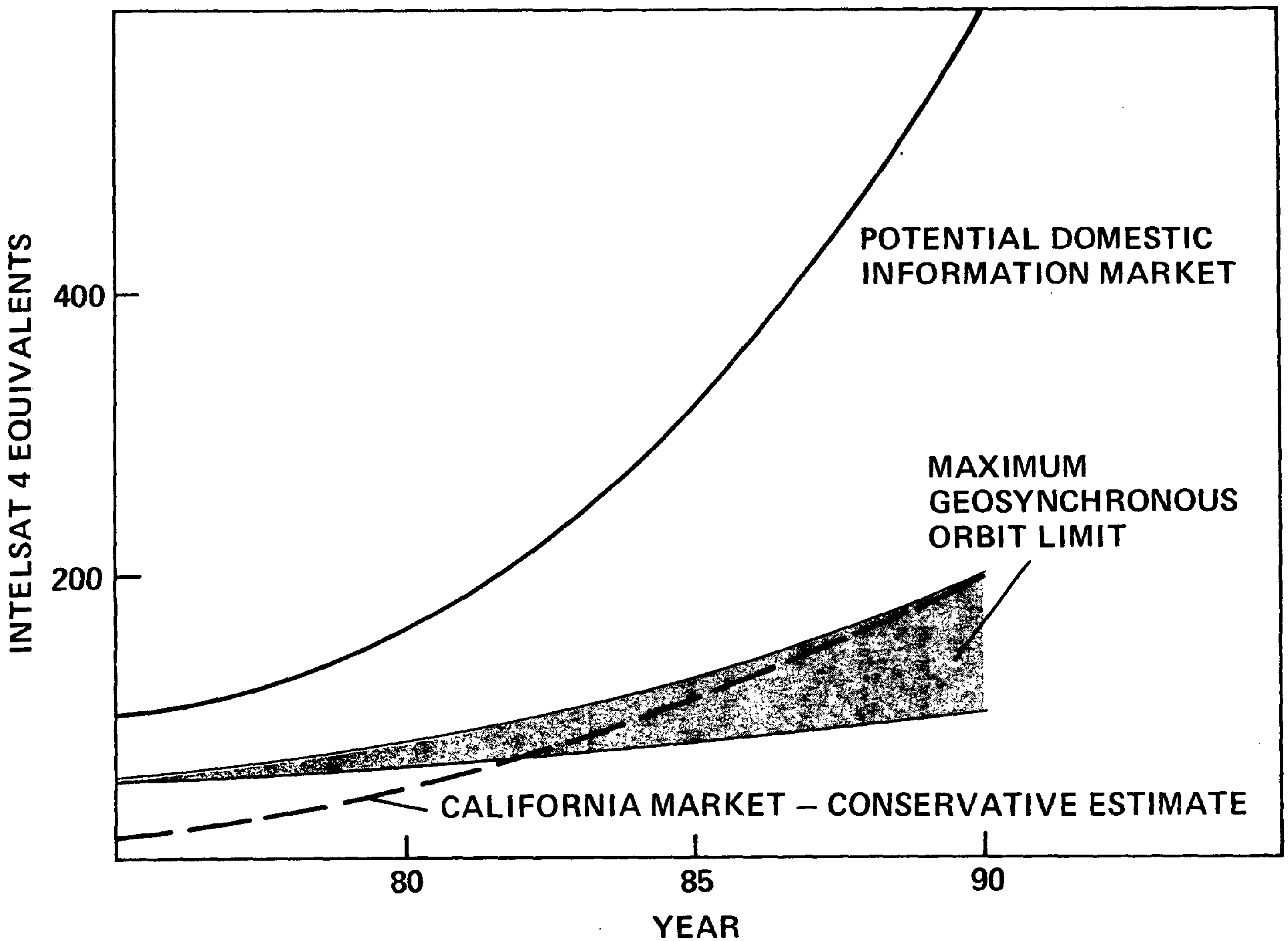
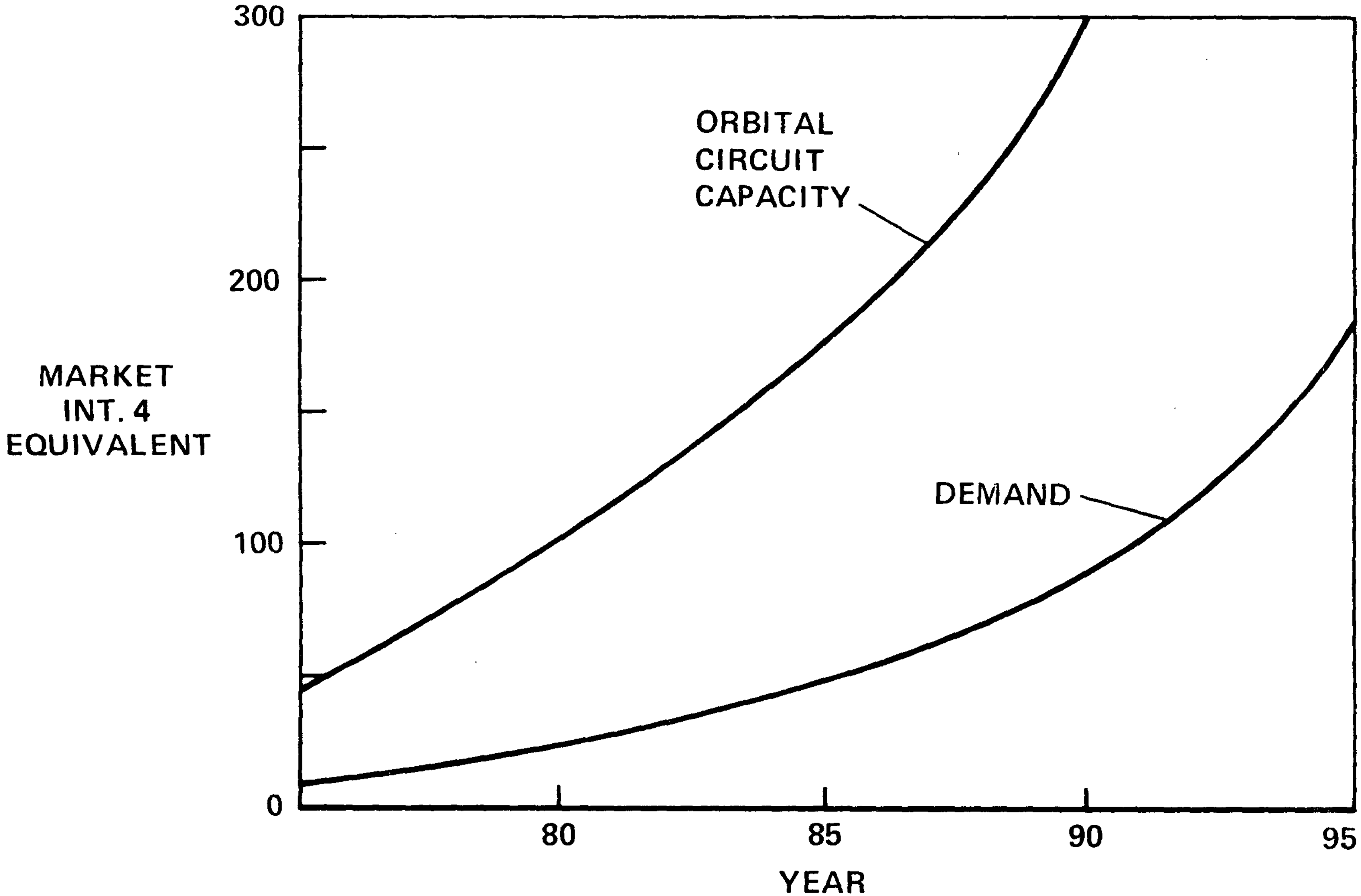
* For the purpose of this report the initial capacity of Intelsat IV is taken as 3000 circuits.

LONG-HAUL INFORMATION TRANSFER MARKET

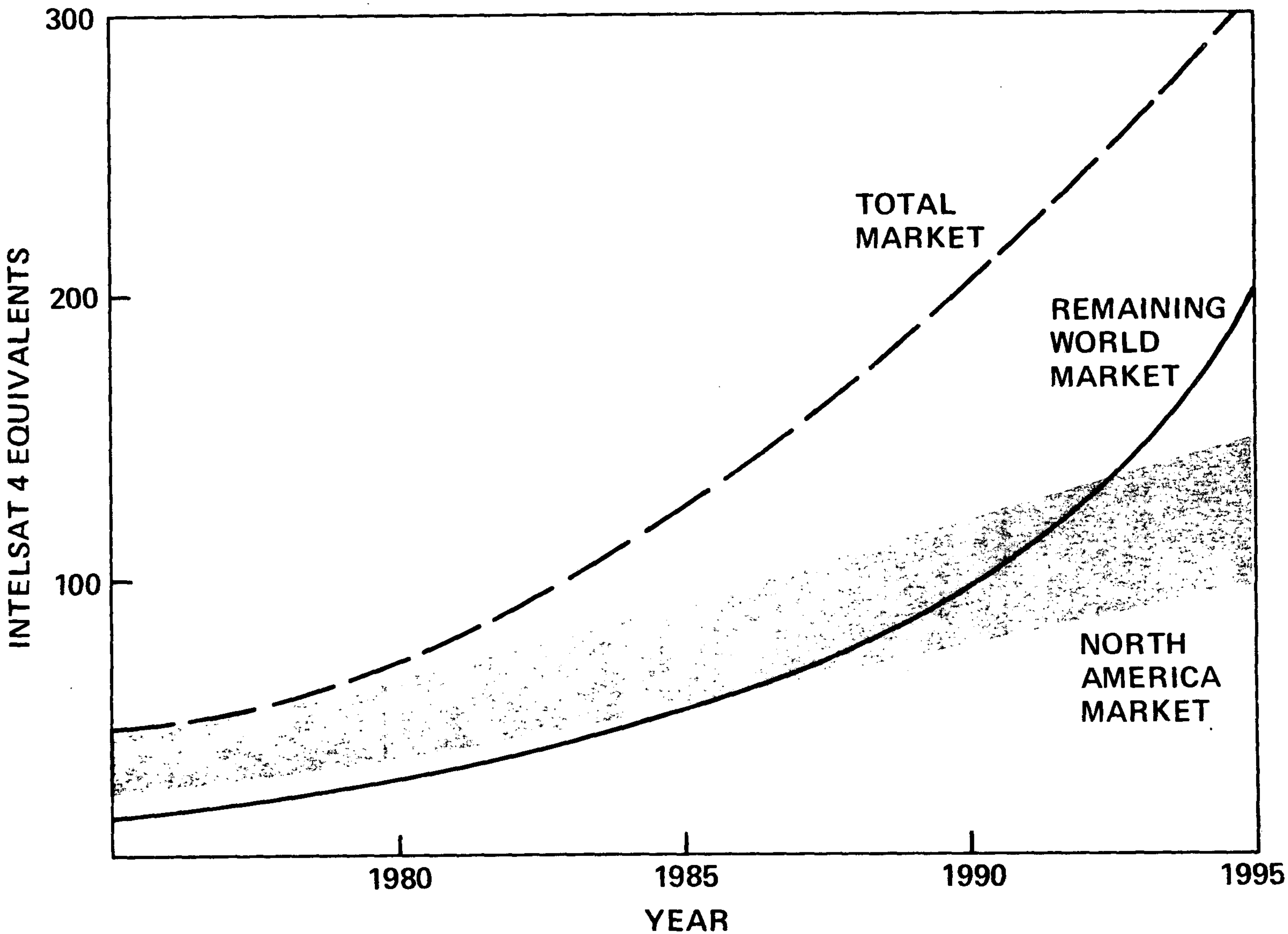


The situation in the rest of the world is not quite as desperate in terms of overcrowding as is the situation in North America. The rest of the world has essentially three times more electrospace to exploit than does North America. Yet at least 90 percent of the communication traffic is presently North American. The rest of the world is not expected to run out of orbit/spectrum space until the 21st century. This comparison has certain implications for the exporting of U.S. communications satellite technology for the future, since the North American market is already constrained and is subject to severe terrestrial competition while the global market is, in the near term at least, essentially bounded only by a demand rate. Although presently low, this demand rate is growing extremely rapidly.

WORLD MARKET—LESS NORTH AMERICA



This curve is merely a summary of the previous two curves and shows the total market for the world less North America versus the North American traffic. It shows that the world market less North America could equal the North American market by the mid 80's to the mid 90's depending on how aggressively the North American market is expanded through electro-space research. Without research to remove electrospace limits the North American market can expand only until orbit saturation occurs while the world market continues to grow.


300
200
100
INTELSAT 4 EQUIVALENTS
TOTAL MARKET
REMAINING WORLD MARKET
NORTH AMERICA MARKET
1980
1985
1990
1995
YEAR

INFOSAT ROLES AND MISSIONS *

This section explores the roles and missions implications of the preceding material for NASA, considering the usage of the available spectrum, the problem of the small user, competition, and so forth.

INFOSAT ROLES AND MISSIONS

- SPECTRUM WASTE VS. SATELLITE LIFETIME
- SPECTRUM WASTE VS. SMALL USERS
- LIMITED ORBIT ARC/SPECTRUM CAPACITY
  - INTENSIFY ORBIT/SPECTRUM RESEARCH
  - RESTRICT TO UNIQUE USES
  - SEARCH FOR UNIQUE USES
- GENERAL ROLES FOR INFOSATS
  - STIMULATE TERRESTRIAL SYSTEM INNOVATION
  - TOE-IN-THE-WATER ROLE
  - EXPORT COMMUNICATIONS REVOLUTION
  - LOAD LEVELLING
  - REMOTE SCIENTIFIC AND OTHER STATIONS

The efficiency of use of the spectrum and orbit space by satellites has increased as the problem and the technologies for dealing with it have become better understood. The longer the lifetime of the early, inefficient satellites that are launched, the longer it will be before another generation of efficient spectrum using satellites will be launched to replace them. Thus, the overall efficiency of orbit/spectrum utilization will generally be inversely proportional to the lifetime of the satellites in orbit.

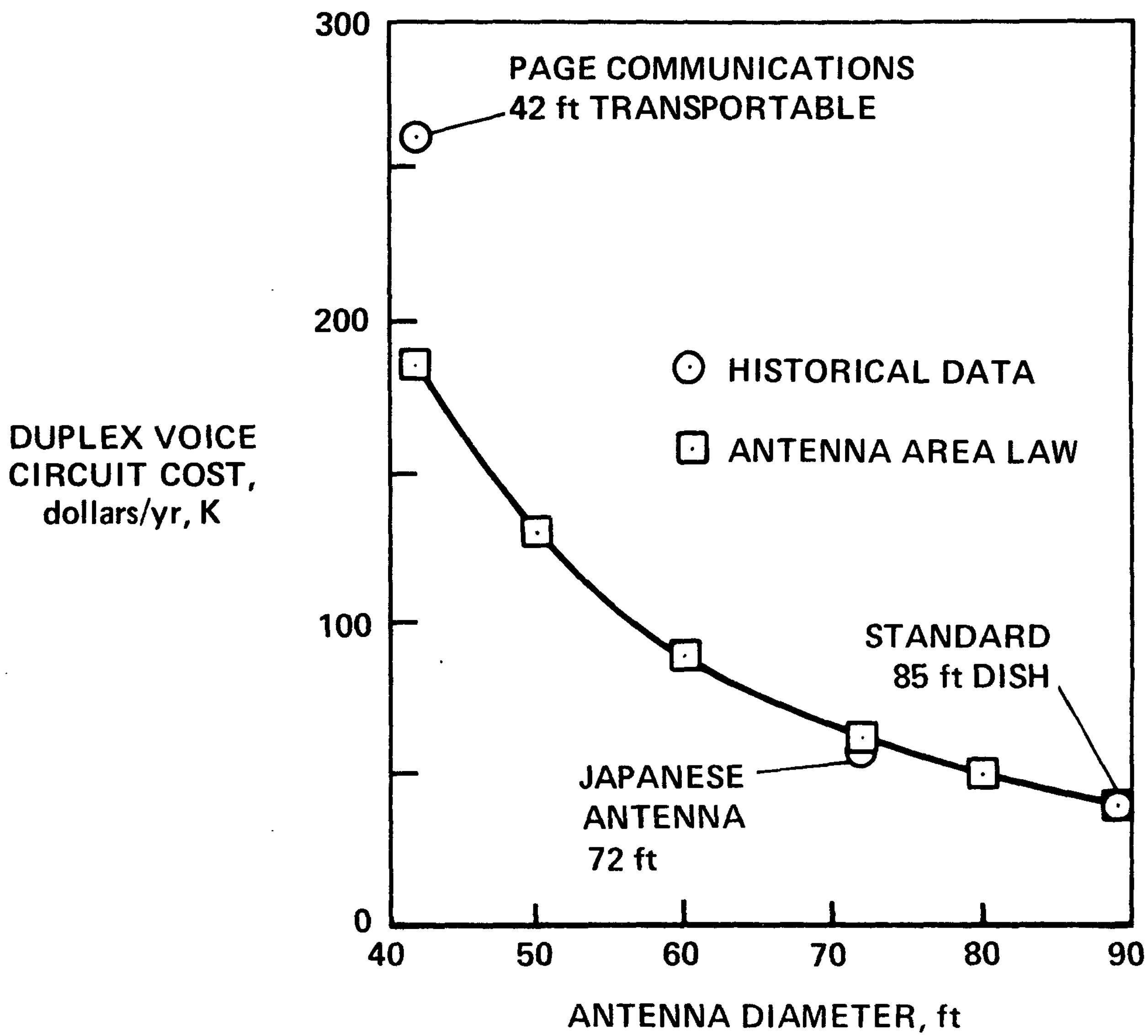
An interesting paradox, however, is that one of the chief ways that lower cost satellites have been achieved is through the continuing quest for longer lifetime satellites. Such expected lifetimes have been increased from six months in the early 60's to ten years at present. Saturation will occur sooner if there is a too hasty launching of ultra long life satellites. The total market from 1975 to 2000 will be maximized by launching shorter lifetime satellites until the technology will permit extremely efficient utilization of the orbit and spectrum. For example, satellites of five year lifetime will give 50 percent better electrospace utilization than satellites of twenty year lifetime, using the geosynchronous limits presented earlier. Therefore, the continued trend to lower cost satellites will tend to reduce the overall efficiency of spectrum use at any given time. These arguments need intensive tradeoff study.

SPECTRUM WASTE VS. SATELLITE LIFETIME TRADEOFF

- SPECTRUM USE EFFICIENCY INCREASES BY THE YEAR
- LONGER INFOSAT LIFE INCREASES PROPORTION OF SPECTRUM WASTING SATELLITES IN ORBIT
- LONGER INFOSAT LIFE REDUCES COST PER CHANNEL YEAR
- QUEST FOR LOW COST INFOSATS THRU LONG LIFE TENDS TO OVERALL WASTE OF SPECTRUM
- TRADEOFF NEEDS INTENSIVE STUDY

Small (low cost) user terminals represent an ideal case of a unique INFOSAT use, situations where conventional means would be impractical for many such as remote or inaccessible locations, sporadic use of high data rate transmissions such as computer graphics, law enforcement, etc. Unfortunately the small users, because of their small, widebeam antennae, and their generally "undisciplined" transmissions are more wasteful of spectrum, orbit space, and satellite power than are the more expensive stations. The dilemma is that those smaller satellite users, who ideally exploit the unique capability of the INFOSAT, do not use satellites as economically as the large users who not only have access to expensive terminals, but who also have alternative systems available to them. Thus, in many ways the small user is overlooked or slighted when systems are configured. Systems are generally optimized for the large user and the small user is required to pay a penalty such as shown on the facing chart based on his non-optimum use of the satellite. Intensive study of this problem should be undertaken with the objective of developing a rationale for including the small user, particularly the very small user, in rate construction calculations and in the planning of future spectrum/orbit conserving satellites.

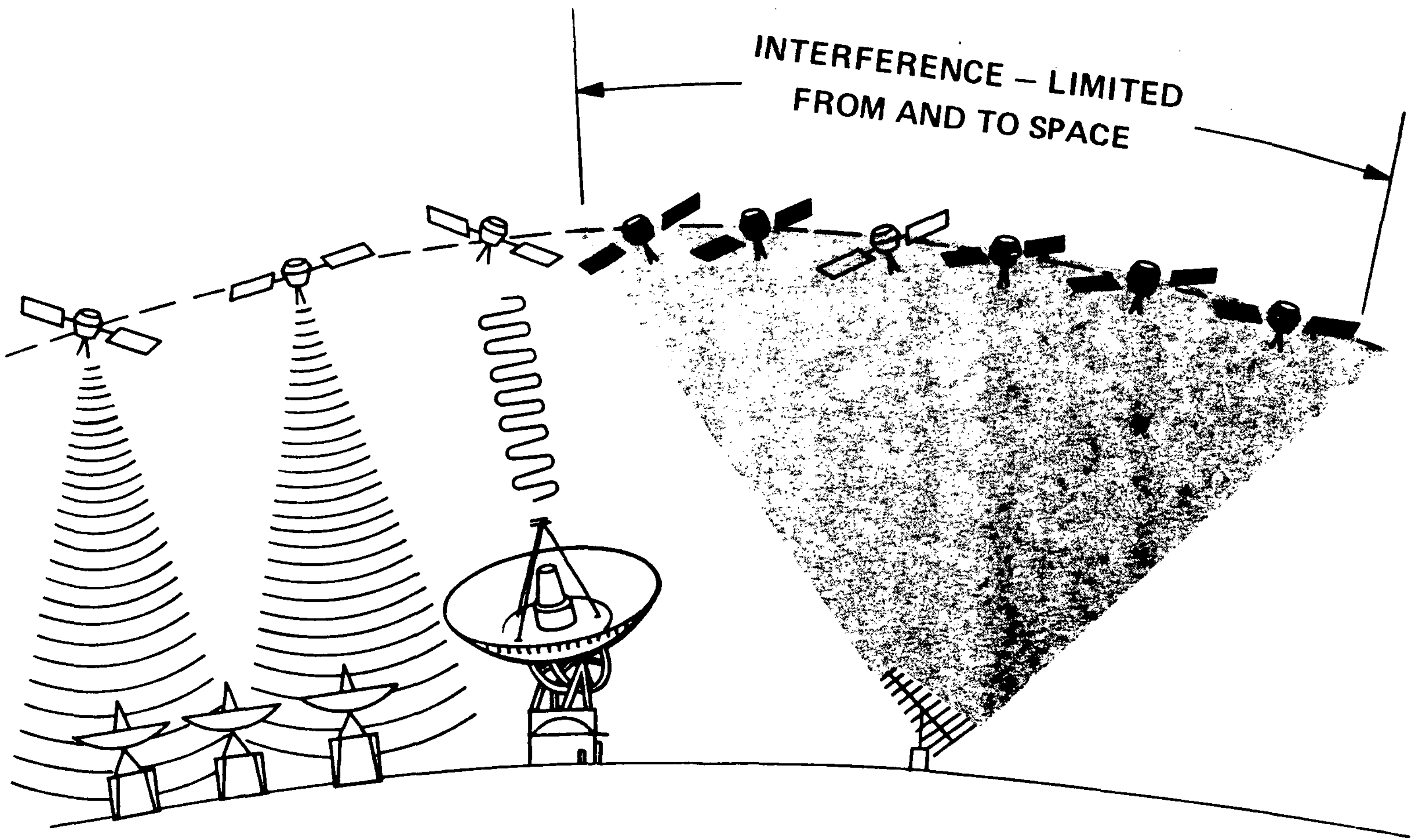
SMALL EARTH STATION USER PENALTY



The limitations on orbit/spectrum capacity suggest that in the future it may be necessary to restrict INFOSATS to unique uses that cannot be met by national grids of coaxial cable and waveguide that more efficiently conserve spectrum. Intensive research should be performed to identify those uses that are uniquely suitable and to identify efficient spectrum utilization technologies that might significantly reduce the ultimate restrictions. A great deal of work is necessary to develop the economic implications of spectrum/orbit, such as determining shadow costs of a "degree-megabit"* of synchronous "electrospace," so that one could include them in system design calculations. For example, in the future it will be important to know just how much we are paying for the "luxury" of including small users in our systems designs, including the cost of the "electrospace" thereby wasted.

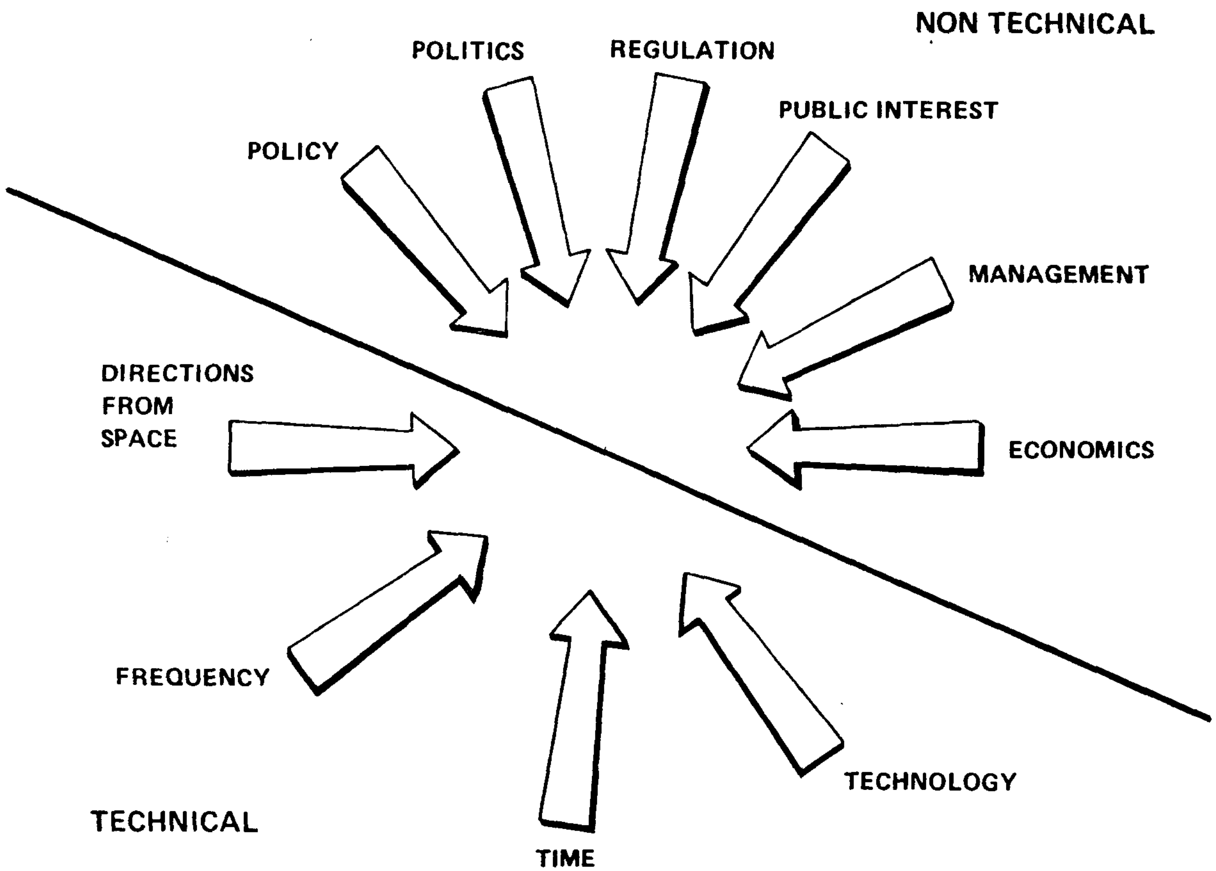
* The shadow cost of a degree-megabit is the price that would be charged, under optimal allocation rules, for the use of 1 megabit of the total capacity of an arc of 1° of synchronous orbit.

ORBIT CAPACITY
GEOSYNCHRONOUS ORBIT



The orbit/spectrum management problem, which as we have pointed out must be solved if the North American market potential is to be realized, has been attacked mostly from the purely electromagnetic theory point of view in recent years. Unfortunately "electrospace" is a natural resource on which highly varied interests converge, thereby creating a complex, multifaceted problem. The technical problems are concerned with the space geometry at a given time and frequency, and with the technological tradeoffs that may be accomplished among these variables. The nontechnical side concerns the equally important, but frequently overlooked, problems of economics, management, public interest, regulation, policy, and even politics. The intersection of all such factors is the arena of the problem, and unfortunately, it cannot be solved merely by concentrating on those aspects that are easiest to measure and compute. The solution will require, and is probably ripe for, true systems analysis--in its broadest multidisciplinary sense.

PARAMETERS OF ORBIT/SPECTRUM PROBLEM



In the telecommunications industry, which is characterized both by extremely large system investments and significant economies of scale, one of the biggest fears is the so-called "cream-skimming" by a low-investment competition who "skims off" a high volume submarket, leaving the low volume markets to the principal common carrier. But the role of the satellite, as we have pointed out, is just the opposite--it will always have a great deal of difficulty taking a high volume market away from the terrestrial competition and must, instead, concentrate on the "thin route" market which it can serve quite easily.

In the future, therefore, whether by evolution or regulation, it will probably be true that cable will be used wherever it can both do the job as well as the satellite and can also preserve the spectrum. The satellite will concentrate on services that it can perform either uniquely or so much better than the cable that order of magnitude cost comparisons will show the difference easily. These uses will include remote small users as a matter of course. Mobile vehicle users will become more and more important as time goes on, probably with aircraft and ships. "Thin-route" wideband traffic will be served as the dimensions of the "wideband revolution" become clearer and it is seen that users not on the main digital network wish to be included and transmit broadband nevertheless. People with sporadic wideband needs, such as certain timesharing applications, computer graphics, or "on-demand" wired nation services may use satellites even if on the main network. Narrowcasting applications or special hookups for sparsely scattered users who are nevertheless a large audience in the aggregate will be important.

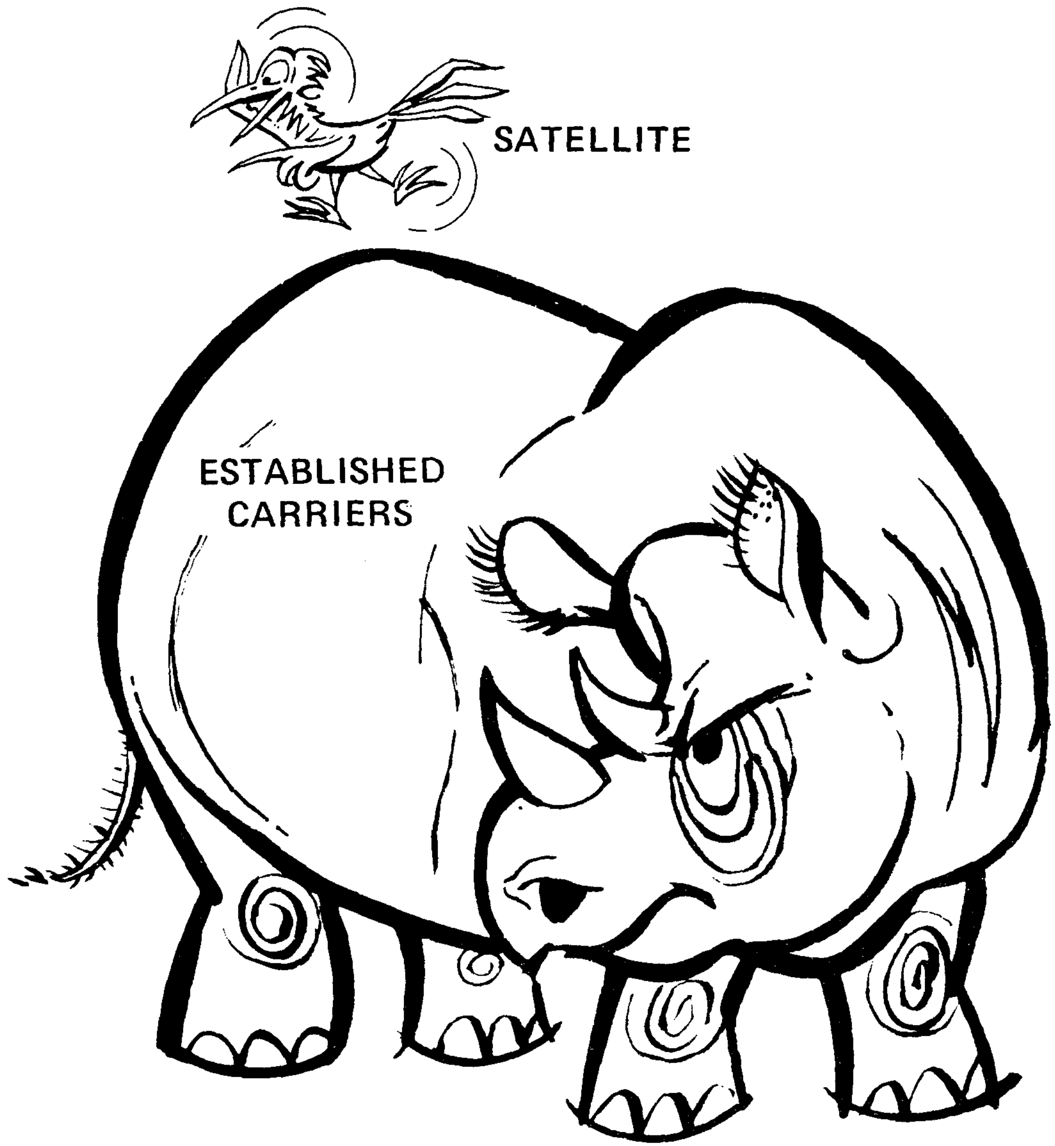
When demand patterns cannot be stably predicted, such as in a limited war area, the satellite will prevail. When it is wished to relay data from a space vehicle to Earth or to another space vehicle the satellite will clearly be preferred. Similarly, the satellite will be preferred when it is desired to balance a lopsided traffic load in a terrestrial network temporarily, while awaiting new construction of links or on a regional emergency basis. In addition, there are myriad "toe-in-the-water" uses in which a new telecommunications idea may be verified using the satellite, at a much lower capital cost than terrestrially, to help make a terrestrial investment decision.

FINDING UNIQUE SATELLITE USES

- SATELLITE ROLE IS "MILKSKIMMING" – NOT "CREAMSKIMMING"
- USE CABLE WHEREVER IT CAN DO THE JOB AND SAVE SPECTRUM
- SPECIFIC USES:
  - REMOTE SMALL USERS
  - MOBILE VEHICLE USERS
  - "THIN-ROUTE" WIDEBAND
  - SPORADIC WIDEBAND
  - NARROWCASTING
  - SHIFTING DEMAND PATTERNS
  - "TOE-IN-THE-WATER" USES
  - SPACE-TO-SPACE RELAY
  - LOAD BALANCING

Whatever the detailed roles of the information transfer satellite may be, one of the most important general roles it can play is to guide the conventional networks into socially useful directions through the threat of competition. Whatever it is claimed the satellite can do, the conventional networks will try to do as cheaply as a reaction to the competitive threat. The massive investments in the conventional system understandably make decisions involving large changes difficult, and changes that are in the public interest exceedingly difficult, without some form of external "threat." As such a competitive "threat" the satellite could conceivably serve as a very creative tool for public policy implementation. The illustration typifies this situation in which the "tick-bird," who lives symbiotically with the rhinoceros, earns his pickings by alerting the rhino to threats and opportunities perceived with his superior eyesight: A very small bird is able to steer the much more massive but slow-to-react rhino into useful directions.

THREATEN CONVENTIONAL NETWORKS WITH INNOVATION

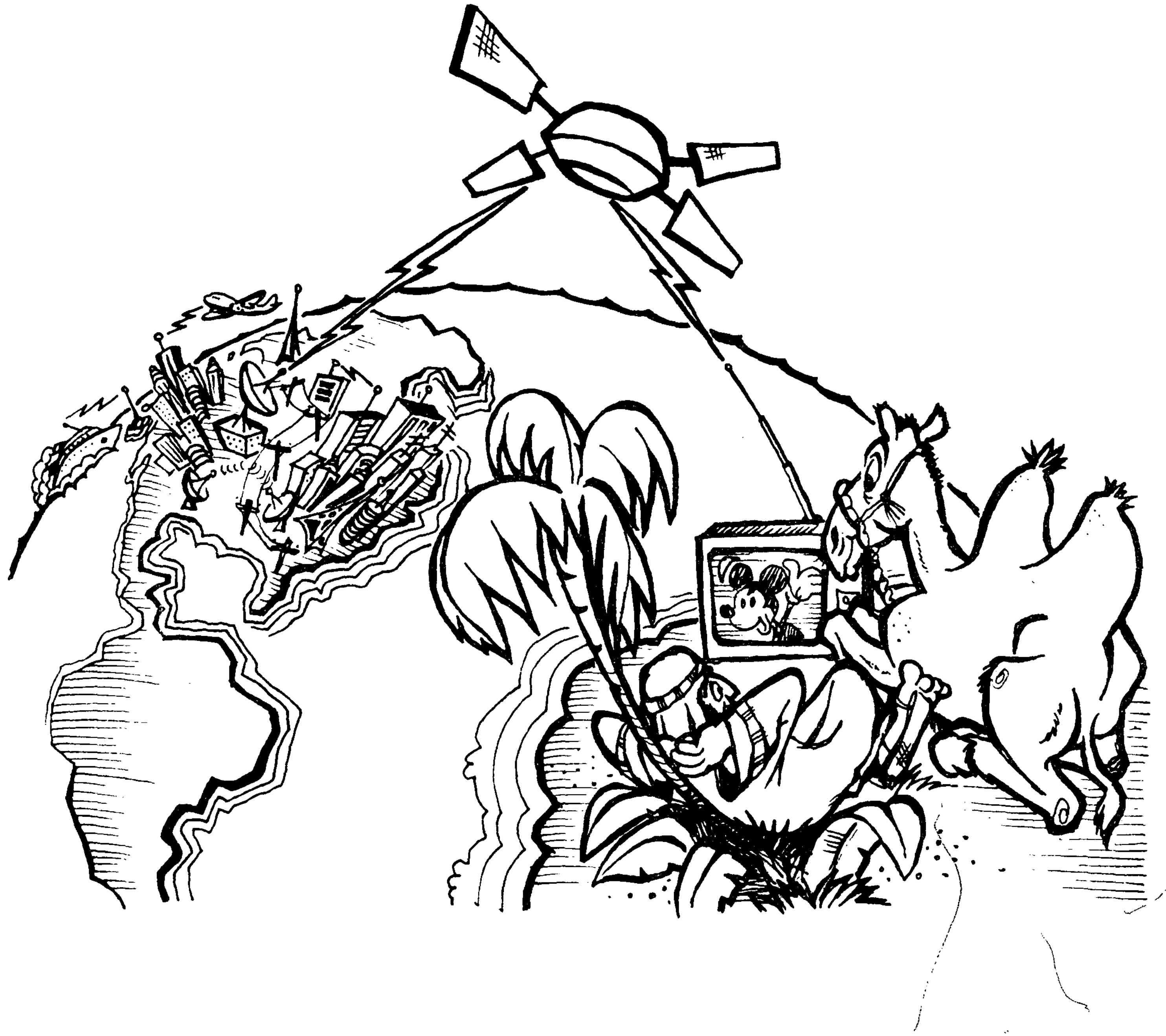


The previous role would be a relatively unrewarding one for an entrepreneur and it would have to be managed carefully to attract any takers. The model of "cormorant fishing" is perhaps more reasonable. The "toe-in-the-water" missions mentioned earlier would substantiate a number of otherwise high risk, but potentially highly profitable concepts that would then be subject to investment by the established carriers generally using other means than satellites for their implementation. But undoubtedly many missions would be discovered that for one reason or another were not attractive investment opportunities for the conventional carriers but that would nevertheless be ideal missions for the satellite. The role of the satellite would then be analogous to that of the cormorant in "cormorant fishing." The fisherman sends the cormorant out to catch fish, which because of the snug ring on his neck the bird cannot swallow, so that he must therefore bring them back to the fisherman. But he gets to swallow all the small fish he can find. Each night, the ring is removed and the fisherman feeds him enough fish to keep him working at his job. Both benefit. The analogy indicates the way that both the terrestrial carriers and the INFOSAT entrepreneur might profit by a similar symbiotic relationship.

THE BIRD GETS TO KEEP THE SMALL ONES

Another key general role of the satellite is in exporting the information revolution to the remainder of the world--the "Global Village" concept. Most of this brochure has had to do with developments and expected developments in information transfer in the United States. Similar phases of the information revolution are already underway in the U.K., in Canada, in Japan, in Europe, etc. The revolution however will be largely limited to the more advanced nations of the world community. It is presumed that if this revolution is as favorable as it is expected to be for human advancement, the other nations of the world will want to be able somehow to partake of the intellectual feast--at least, the intelligentsia and affluent classes of the advanced nations will want to do so. The information transfer satellite appears to be an excellent way to do this. The cultural and political implications are staggering. If certain countries cannot yet allow their populations to see television because of its political impact, the problems to be raised by exporting the communications revolution to the rest of the world, with all of its presumably even more powerful tools than television, are impossible to comprehend.

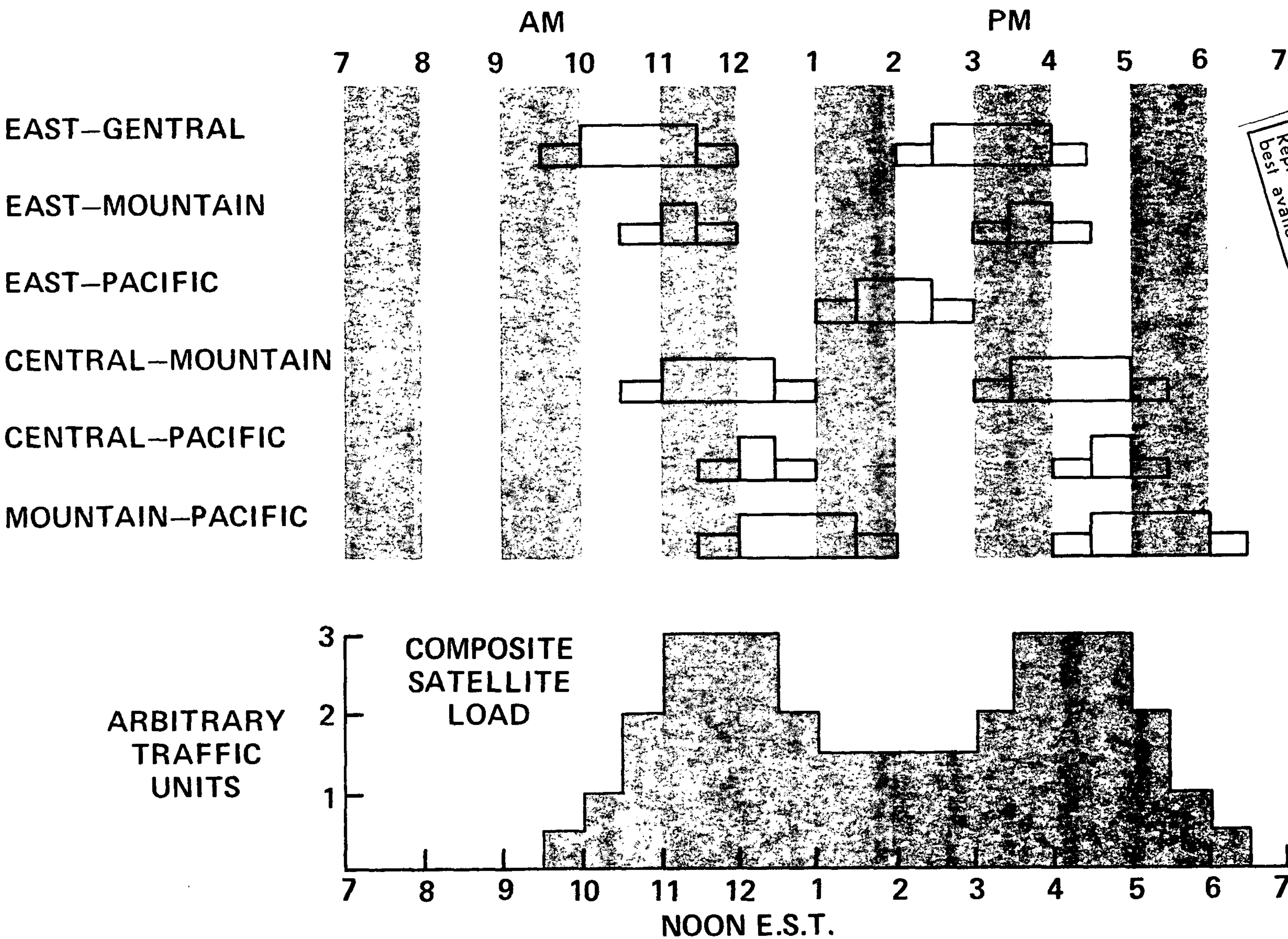
EXPORTING THE INFORMATION REVOLUTION—"GLOBAL VILLAGE"—



We have already mentioned the opportunities for "load-leveling" and the curve on the facing page reinforces this concept as a generally important role for satellites. The common carriers have already been thinking of such potential uses for the satellite and have every intention of using them in this way.

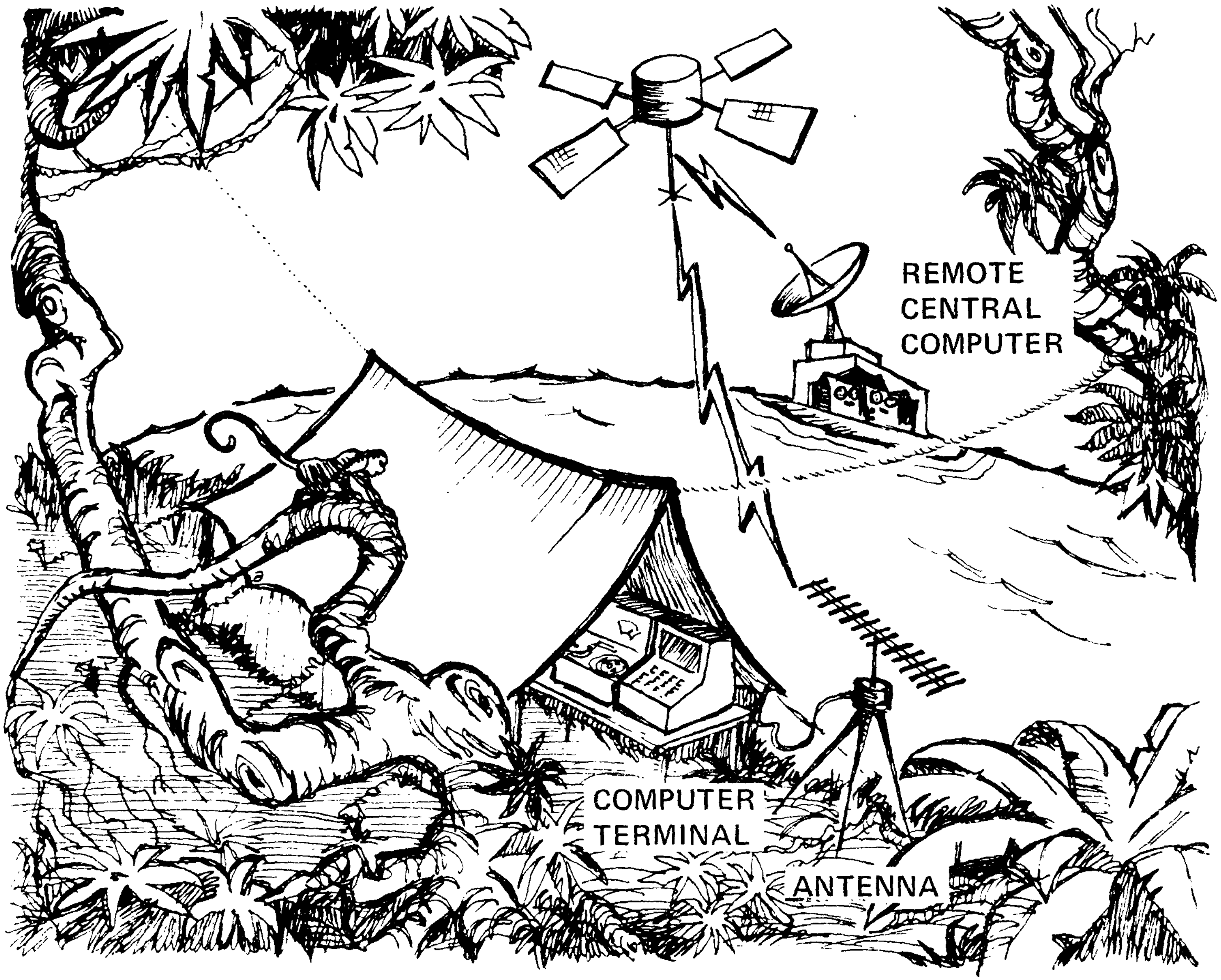
Because of overlap of the business day, communications from one time one to another have characteristic peaks that occur at different time, G.M.T. Cables or microwave links connecting time zones are therefore subject to low utilization rates because they must be designed to handle peak traffic and are consequently overdesigned for the average traffic load. INFOSATs synoptically "see" all combinations of time zones and are thus able to average the various peaks quite effectively; the satellite thus has a better inherent utilization factor.

LOAD LEVELING IS AN IMPORTANT INFOSAT APPLICATION



The use of satellites for relaying data from tens of thousands of ocean buoys, hydrological platforms, volcanic sensors, etc., is an important future use. Experimental work is already underway and studies such as the National Data Buoy Program help insure that such a concept will ultimately come about. Another important use in the future may be to interconnect scientists throughout the world--particularly those in remote field parties, Antarctic exploration sites, archeological sites, etc.--into the network of powerful computers that are becoming an increasingly important part of their work. Satellites are ideal for this application.

REMOTE SCIENTIFIC, ENGINEERING, EXPLORATORY PARTY ACESS TO COMPUTING POWER



CONCLUSIONS *

It would be impossible to perform a study of this scope without drawing at least some tentative and broad conclusions. We present these conclusions here. They are divided into conclusions concerning the future, needs, applications, staffing and NASA's role.

CONCLUSIONS

- FUTURE
- NEEDS
- APPLICATIONS
- STAFF
- NASA'S ROLE

NASA's role is such that it does not seem reasonable for it to become extensively involved in near term research. But it is vitally important that some national institution does concern itself with the farther future so that the public interest aspects of satellite development can be furthered. Industry is actively working on near term satellite development, as has been shown, to the extent of tens of millions of dollars a year. The domestic satellite will further stimulate nearer term research and development.

The information transfer satellite has an extremely promising future if the research and development leading to farther future missions, spectrum management, satellite design, etc., is done in a timely fashion. NASA's charter and capabilities ideally suit it to this future-oriented role if the role can only be grasped. NASA can perform the complementary function of tending to those aspects of information transfer satellite development that industry cannot or will not, by its very nature, consider. For example, there are certain developments which would forever be overlooked if considered only from a single-mission standpoint. It may be that the decision to develop or not develop sophisticated space-borne phased array antennae could never be made if the missions which it would support were considered one by one. And yet a comprehensive programmatic study that considered such antennae from a multiple mission point of view might determine that they were superior in some sense--such as spectrum conservation--and a decision might be made to support more intensive research in this area as a national and NASA objective. Many more such instances can be enumerated.

CONCLUSIONS - FUTURE

- LITTLE NEED FOR "NEAR TERM" NASA RESEARCH/TECHNOLOGY
- INDUSTRY TRADITIONALLY LITTLE CONCERNED WITH FAR FUTURE
- INFOSAT HAS BIG FUTURE IF FUTURE-ORIENTED WORK IS DONE
- MULTI-MISSION SETTING REQUIRED FOR TECHNOLOGY FUTURE NEEDS

It is probably clear from reading this brochure that the demand for INFOSATS is immense and rapidly growing and that if the proper steps are taken, such as considering the competition, uncovering unique uses of satellites, etc., that demand will not be the limiting factor.

Satellites cannot do the entire job alone and all planning must start from this assumption. Therefore, great care must be exercised in selecting unique applications for the satellite, and missions must be avoided that can be somehow done by competing media. A particularly important criterion is to concentrate on the more socially important missions, since satellites cannot do them all. A corollary of this assertion is that there needs to be a dynamic effort to "smoke out" the users who have uniquely suitable INFOSAT missions. This absolutely cannot be done by passively waiting for users to contact NASA, searching for an attentive listener, but must be done by an active "user bridge" process, involving a special NASA systems analysis staff who concentrate solely upon this activity.

CONCLUSIONS - NEEDS

- DEMAND IMMENSE – NOT LIMITING
- SOCIAL IMPORTANCE CRITICAL
- INFOSATS ALONE CAN'T DO IT ALL
- UNIQUE APPLICATIONS EMPHASIS NEEDED
- USER NEEDS RESEARCH FOR UNIQUE NEED DETECTION
- BASE ORGANIZATION OF APPLICATIONS ON "USER BRIDGE"

In general, and with the exception of a few of the most obviously pure satellite missions, the satellite is not a self-standing system. It requires integration with a ground network of greater or lesser complexity, such as a microwave network to distribute the satellite signal among a group of local users, the ARPA network, etc. The degree of understanding of such non-satellite portions of the total satellite system was found in this study to be almost nil in the satellite industry as a whole and NASA in particular. A great deal of emphasis should be given to developing the knowledge of these complementary non-satellite portions of the total system within NASA so that total systems designs can be intelligently handled in the future. In addition, some of the most important INFOSAT roles have been seen to be imbedded in the non-satellite industry structure, such as the load balancing and toe-in-the-water roles. NASA should attempt to develop sufficient familiarity with all the important network characteristics to permit it to work effectively in the area of future satellite R&D in the public interest. Without such familiarity, many of the most important missions would almost certainly be overlooked. Again, without such familiarity with the essentially complementary nature of satellites and ground networks, it becomes too easy to take the point of view that satellites are in "competition" with ground systems for the same missions. This point may not be easy for NASA to address itself to without the addition of staff familiar with the intricate problems of working with terrestrial networks and the design of such networks.

CONCLUSIONS - APPLICATIONS

- SATELLITE NOT SELF-STANDING
- ALTERNATE/COMPLEMENTARY NON-SATELLITE SYSTEMS REQUIRED
- KEY INFOSAT ROLES EMBEDDED IN TERRESTRIAL NETWORK USES - MUST STUDY
- PROPER INFOSAT APPLICATION REQUIRES COMPREHENSIVE NETWORK OVERVIEW – SATELLITE/NONSATELLITE COMPONENTS

Many of the staffing conclusions have already been briefly mentioned in connection with other conclusions of the study. It appears that a greater emphasis should be given to forming a staff to protect the small user option which, although one of the most important application technologies, could very easily become lost in the rush to "spectrum-efficient" satellite options. There is a need for future-oriented people and needs-oriented people who, together, can identify future unique uses of satellites so that satellites will not remain in the "misapplication phase." The nontechnical issues have been shown to be a highly important factor in information transfer satellite progress, more important even than the currently envisioned technological issues. Yet NASA in spite of its broad 1958 charter has few people who are able to explicitly address themselves to these nontechnical issues outside a few notable managers who have a good intuitive feeling for such issues. The staff work required when facing such issues on technology-oriented projects has been largely lacking.

Although not purely an issue of staffing, this is perhaps the place to mention the need for a much better working definition between operational and "proto-operational," or operational versus research roles. The staff should not have to back away (in fact, must not back away) from thinking and planning in an operational context when considering INFOSAT technology simply because it has been (apparently) decided that NASA will not generally take an operational role in applications programs. This problem of apparent confusion over operational vs research roles was mentioned by a surprisingly large fraction of the 500 or so users contacted.

CONCLUSIONS— STAFF, ETC.

- STAFF TO PROTECT "SMALL USER" OPTIONS
- AVOID "MISAPPLICATION PHASE"
- STAFF TO ATTEND TO POLICY AND OTHER NONTECHNICAL ISSUES
- BETTER DEFINED OPERATIONS VS. RESEARCH BOUNDARY/CORRESPONDING ROLE AND STAFFING CHANGES
- STAFF TO EMPHASIZE
    - SYSTEM ANALYSIS
    - POLICY ANALYSIS
    - FUTURE CONCEPTS
    - NONSATELLITE ALTERNATIVES
    - ACTIVE USER INTERACTION

In the course of the study it was difficult not to spend some time thinking about the impact of our findings on NASA's future role. In fact, this was the most frequently asked question about the study results. It is impossible to escape the conclusion that there is a tremendous future role for NASA in this burgeoning field if the proper steps are taken to grasp it. These steps, unfortunately, may have to involve modest staffing increases in certain areas and slight changes in staffing emphasis in other areas. Without any further discussion of the specific staffing changes which have been mentioned during the study, but which are clearly not our responsibility, perhaps it will suffice to briefly review the new emphasis that was found to be desirable. The emphasis should be upon the missions of the 1980's, not the missions of the 1970's. This will permit an assessment of the technologies that should be studied and developed in the 1970's which near term studies could never provide. NASA must become more needs-directed. There are so many technological directions that might be taken that the discipline of user-orientation must be applied to reduce them to a tractable number. NASA must therefore staff and organize to meet the users at least halfway. The start taken by the Earth Resources Programs in this direction are commendable, but even they can be immensely improved upon. Unique applications must be sought, thereby partially eliminating the problems of competition with existing entities that retard satellite development. Another step in the direction of minimizing the competition problems is to become much more aware of the threat and potential for sharing inherent in the non-satellite alternative systems. Above all, we must learn not to treat users merely as principal investigators on a science-oriented experimental satellite basis but rather to learn to actively work with them in developing their requirements intelligently and mutually. If these steps are taken NASA will play a significant role in the development of INFOSATS for the benefit of mankind, and will thus live up to the farseeing charter that was provided for it in the Space Act of 1958.

CONCLUSIONS — NASA'S ROLE

- SIGNIFICANT ROLE IF GRASPED
- EMPHASIS NEEDED:
  - FUTURE, NOT NEAR TERM TECHNOLOGY
  - BECOME NEEDS - DIRECTED
  - MEET USERS HALFWAY
  - SEEK UNIQUE APPLICATIONS
  - AVOID SELECTING APPLICATIONS ON SCIENCE CONTENT
  - BECOME AWARE OF NONSATELLITE COMPETITION AND COMPLEMENTARITY